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Installing New Blast-Furnace Plant

The evolution of an entirely new blast-furnace plant is an event of infrequent occurrence, and the principles which guide the general planning, the selection of auxiliaries, and, to some extent, the details of design, are of considerable interest. This is particularly true of the plant recently erected at the Dagenham Works of the Ford Motor Company, which involved so much preparatory work in view of the marshy character of the site.

The blast-furnace, stores, and cast-house.

IN such an undertaking an exhaustive technical and commercial study of the whole project is essential before engineering proper is commenced, and to establish the size and type of all the leading features, equipment, auxiliaries, calls for the participation of technologists versed in many branches of engineering science. Civil, mechanical, electrical, chemical, metallurgical, and combustion engineers all have their specified rôles to play, and collaboration amongst them under unified guidance goes far to ensure the success of the plant.

A full account of all the deliberations which lead to each and every decision would prove too voluminous. Major W. R. Brown, who made special reference to this installation in a paper before the Iron and Steel Institute on May 5, recorded some of the more important considerations in the choice and erection of the plant. Two examples were reviewed to show that individual characteristics impose themselves upon the general planning, making each plant peculiar to its own conditions and environment. In the case of the Ford plant, the blast furnace may be regarded as an auxiliary of an automobile factory, and is required to manufacture a single special grade of foundry iron from materials which are water-borne.

Raw Material Handling.

A very thorough effort has been made at Dagenham to extract the maximum monetary advantage by rapid discharge of the ships carrying ore, coal, and limestone. The wharf arrangements are the most up to date in the Port of London, and can accommodate ore-carrying vessels up to 12,000 tons. The discharging appliances consist of two unloaders, of Mead Morrison design, running on an elevated high line, 500 ft. in length, above the wharf proper. The unloaders are of the man-trolley type, with a reach of 40 ft. over the water. Six-ton grabs are used, and these discharge into two 50-ton weigh-hoppers on the first deck of the unloaders.

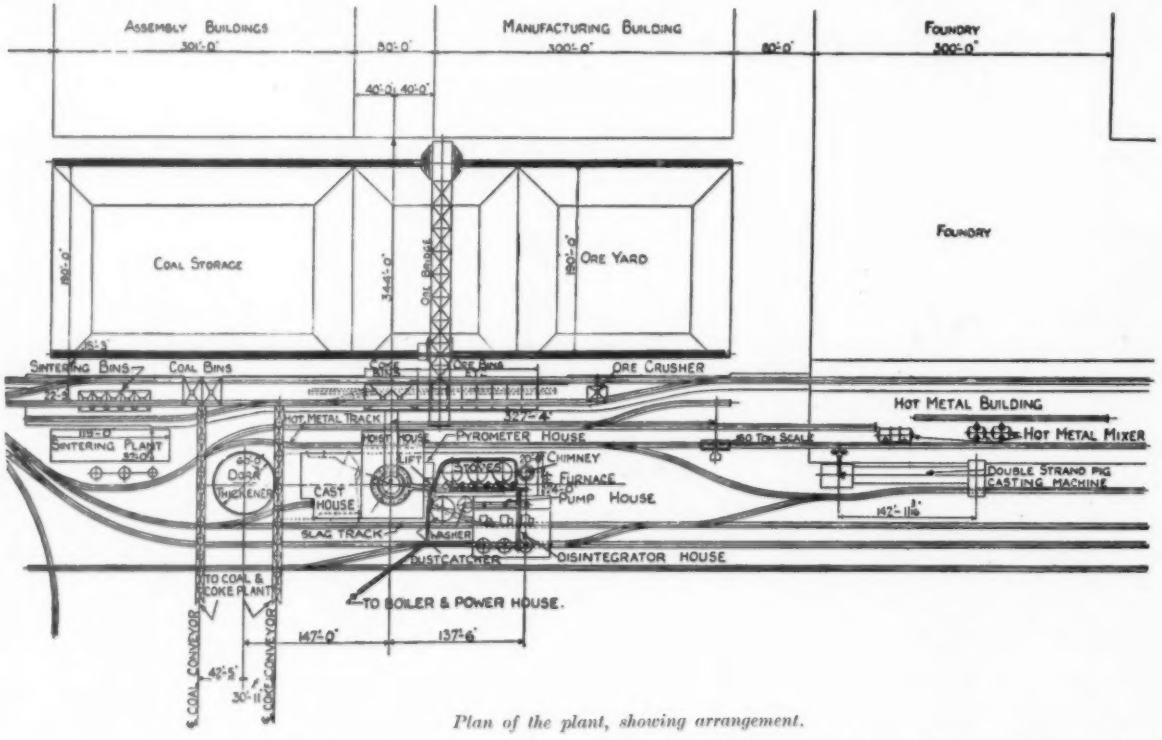
The high line connects with the shore, and, maintaining the same elevation throughout, traverses in turn the sinter-plant bins, the coal-transfer station, the furnace bunkers, and the ore-crusher bunker, and terminates within the hot-metal building where foundry coke is delivered for the cupolas. On the western side of this high line for nearly 700 ft. there lies the stockyard, consisting of an ore trough 15 ft. in width, and a yard 195 ft. wide, the whole area being covered by a reinforced concrete mat carried on piles. The yard provides stocking for 135,000 tons of ore and limestone and 33,000 tons of coal.

Two self-propelled 50-ton electric transfer cars operate on the high line, drawing materials from the weigh-hoppers of the unloaders, and, bringing it ashore, side-dump their load either into the ore trough for stocking or directly into the bunkers at the furnace or sinter plant. Besides these transfer cars, there is also a reclaiming car of 50% larger capacity, primarily intended for handling coal. All these cars are fitted with air-operated dumping doors and brakes, induction time-limit control with mill-type motors, and, as a safety measure, dead-man control on the drive. A fourth car completes the rolling-stock equipment on the high line ; known as a trailer car, this receives the sinter

from the continuous-process sinter plant, and at intervals is towed by a transfer car for dumping either into the furnace bunkers or into stock. When unloading proceeds simultaneously with furnace operations, considerable activity will prevail upon the high line, and automatic switches are necessary to facilitate rapid operation of the traffic.

The stockyard is spanned by a bridge with an 11-ton grab, which with semi-trained operators has already handled 800 tons of ore in an hour. Both bridge and unloaders represent absolutely the most efficient equipment of their type, and are fitted with rail clamps, which must be released electrically in order for the bridge to move. In case the bridge is travelling and a gust of wind at high velocity strikes it, all electric power is cut off the travel motors, and rail clamps are automatically applied by means of an electric recording anemometer.

A detailed study needs to be made of the interrelation between the various units composing the material-handling equipment, and the schedule of operation for this plant shows that all the normal requirements of the furnace, coke-ovens, and sinter plant can be served concurrently with the unloading from ship and stocking of 5,000 tons of ore in a 24-hour day, allowing a margin of 10 to 15% for time lost on various stoppages and in changing shifts. The task can be better appreciated when it is realised that the normal requirements may involve the reclaiming from stock of some 1,000 tons of coal, which is dumped in the transfer bins *en route* for the coke-ovens; the reclaiming from stock and transport to the sinter plant of some 700 tons of fine ores; the return of the sintered materials to the furnace bins or stock; the reclaiming and distribution to furnace bins of natural ore (unsintered) and limestone; the unloading from wagon and transport to the sinter plant of pugged flue dust; and the transport to the cupolas of foundry coke. Thus a full day's work may comprise the handling and distribution between a complexity of loading and discharge points, of well over 8,000 tons of materials by equipment operated by nine men per shift. Coke is conveyed by belt from the preparation plant at the coke-ovens, and the furnace bunker is trimmed by an automatic tripper.



Plan of the plant, showing arrangement.

Furnace Stack.

The furnace, the lines of which are illustrated, has 10 tuyeres, and the construction of the hearth jacket, which is cooled by sea-water, consists of a heavy mild-steel plate encircling cast-iron staves through which the cooling pipes are carried. The furnace employs a heavy mild-steel plate tuyere jacket, and a banded bosh with copper cooling-plates. Intensive shaft cooling was considered necessary, and the type of cooler to be used above the lintel was the subject of much thought. Those open to the atmosphere have much to commend them, but in practice they have certain fundamental weaknesses. The inability to increase the water circulation when a hot spot develops, a proneness to spillage, or if spillage is avoided, a multiplicity of piping, discount the advantages of this system. The alternative is to use a closed system of coolers, fed in horizontal series, with the inlet carefully controlled, so that the pressure within the block is no more than sufficient to carry the circulation through, say, four cooling blocks. This alternative has been adopted at this furnace, but it would perhaps be not unreasonable to say that the ideal stack-cooling system has yet to be found. The construction of the lintel and casing is notable for the weight of materials used. The former, built of heavy plate-work and angles, forms with the bottom tier of the casing a girder of great strength, and no interior brackets or supports, which interrupt the brickwork, are required. The large diameter of the furnace called for a cast-steel bell and hopper.

The firebrick lining is built entirely of 9 in. and 13½ in. machine-pressed brick squares, keys, and arches. High-alumina bricks are used in the hearth and bosh, and special attention is paid to the grain texture of the shaft lining to resist abrasion by the charge and impenetration of gas. The original lining is so designed that for a subsequent campaign the furnaces can be increased 9 in. in diameter by using walls 4½ in. less in thickness.

Cast-House.

The cast-house, which is partly enclosed by sides with glazing, is served by a 10-ton overhead crane, and sidings are so arranged that materials can be off-loaded from

wagons. Runners, dams, and shutters are heavy iron castings; three spouts on one side of the house extend over the hot-metal ladles, and three on the other side extend over the slag ladles. A double-barrel piston gun is used to plug the tap-hole.

A well-thought-out grouping of controls and indicators centralises the operation of the furnace, and it is novel to find the turbo-blowers and gas valves immediately under control from the cast-house.

Charging.

Dry-quenched coke will be used, and this, after thorough screening, is conveyed to the furnace bins by belt, so no further extraction of breeze should be necessary. The absence of moisture renders it advantageous to charge the coke by weight; this is automatically carried out by weigh-hoppers discharging into the skip-tubs.

Ore, stone, and other materials are withdrawn from the bunkers through a continuous line of Freyn double-lip bin-gates. Ten-ton Atlas scale cars operate these gates by compressed-air cylinders, and, conveying the materials to the dumping point, deposit them in the skip-tubs. A series of interlocks prevents the cars from being discharged when not correctly placed over the skip which is down, and also prevents the cars from being driven with the dumping doors open. The scale-cars, like the transfer cars, are fitted with air brakes, air-operated dumping doors, dead-man control, and all equipment to fit them for continuous and efficient duty.

Double skips are used, and the hoisting apparatus are replete with automatic and emergency brakes, slow-down and slack rope limit switches, etc.

The distribution of the materials entering the furnace is effected by means of McKee revolving distributors. The large and small bells are operated by air cylinders working on blast pressure, with compressed air through a reducing valve as a stand-by. The design of the bells and operating equipment is such that the large bell can be lowered when empty against 30 in. W.G. pressure of gas in the furnace top, and yet will remain closed when fully charged, even though there is no air pressure in the cylinders or gas pressure in the furnace. Freyn continuous stock-line recorders are used. These tell a plain story of the movement of the burden, and an intelligent study of the chart can be of great assistance in diagnosing the conditions within the furnace.

View of the wharf showing one of the unloaders and a Transfer Car in the foreground.

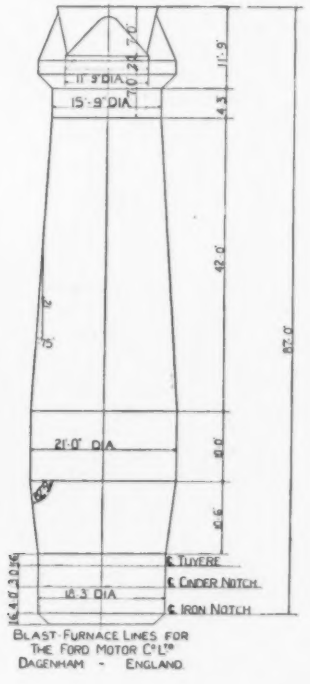
The sequence of operation of all moving parts of the charging gear is governed by the charging control panel. A skip-tub having been filled, the scale-car operator needs only to press a button, the skip ascends and dumps into the distributor, the latter rotates, the small bell opens, and at the correct interval the stockline recorder test-rod withdraws and the large bell dumps. A multiplicity of cycles can be arranged between the small and large bell dumpings. This charging control furthermore acts as a safety device, for if any feature fails to function the whole system stops, thereby immediately calling attention to the irregularity. This highly mechanised charging is warranted by the assurance of operating regularity by the elimination of human error, and by permitting the attention of the sole operator at the scale-car to be concentrated upon weighing, the accuracy of which can be checked by the weight-recording charts.

Stoves.

In considering stove equipment, attention may be confined to only such types as will secure the maximum economy of gas, and so secure the largest credit for the costs account. Such types of stove demand the use of clean gas with a dust content of 0·02 gr. per cub. ft. or less. This condition permits a selection to be made from among several systems of checkerwork, each supported by varying claims to superiority. At this plant the Schiffer-Strack system has been adopted. The checkerwork is scientifically designed, and provides an exceedingly large area of effective heating surface. The word "effective" may well be emphasised, as deep recesses, sharp angles and corrugations —traps for inert gas—are not relied upon to augment the heating area.

The stove fillings consist of hexagonal checkers, those in the top 20 ft. to 24 ft. having a single 8-in. round passage-way, those in the remainder being pierced by nineteen $1\frac{3}{4}$ in. circular holes. Between these two sections, intercommunication is provided by two rows of 7-hole checkers. The corners of the hexagons are recessed, and make additional passage-ways throughout the filling; also, lateral passages permit the gases to distribute themselves evenly throughout the whole cross-section.

The details of the heating surfaces, free areas and brick volumes, are as follows :—



Top Section :

Percentage of total checker volume in section ..	19·8%
Heating surface per cub. ft. of checkerwork	3·74 sq. ft.
Free area per sq. ft. of checker area.....	0·434 sq. ft.
Brick volume per sq. ft. of heating surface	0·138 cub. ft.
Brick volume per cub. ft. of checkerwork	0·566 cub. ft.

Intermediate Section :

Percentage of total checker volume in section ..	1·7%
Heating surface per cub. ft. of checkerwork	8·19 sq. ft.
Free area per sq. ft. of checkerwork.....	0·47sq. ft.
Brick volume per sq. ft. of heating surface	0·058 cub. ft.
Brick volume per cub. ft. of checkerwork	0·530 cub. ft.

Bottom Section :

Percentage of total checker volume in section ..	78·5%
Heating surface per cub. ft. of checkerwork	11·29 sq. ft.
Free area per sq. ft. of checkerwork.....	0·423 sq. ft.
Brick volume per sq. ft. of heating surface	0·046cub. ft.
Brick volume per cub ft. of checkerwork	0·577 cub. ft.

Average of Entire Checkerwork :

Heating surface per cub. ft.	9·75 sq.ft.
Free area per sq. ft. of area	0·445 sq. ft.
Brick volume per sq. ft. of heating surface	0·06 cub. ft.
Brick volume per cub. ft. of checkerwork	0·555 cub. ft.

Examination of the bricks will show that penetration of heat inwards from the surfaces brings the whole brick volume into useful service, and that in the zone of high temperatures a larger ratio of brick weight to heating surface is provided than lower in the stove, where one can afford to reduce the former and increase the latter. The cavities formed at the spigot joints between successive layers of checkers fulfil a special function by permitting a certain turbulence in the gas emerging from one checker before re-entering the next.

There are three stoves which measure 100 ft. × 20 ft., having heating surfaces of 140,000 sq. ft. per stove. The space between the brick lining and the stove shell is filled with insulating material.

The checkers are built up on cast-iron shoes standing on steel grids and girders, which in turn are supported by hematite cast-iron columns. The grids are of special heat-resisting steel.

These stoves are fitted with two Freyn-design chimney valves, Freyn-design Mathesius hot-blast valves, and Freyn-design pressure gas burners. The chimney valves are uncommonly rapid in operation. The hot-blast valves have bronze water-cooled paddles and seats, and are exceedingly blast-tight, a matter well worth consideration, as loss of blast is a direct addition to costs. All facilities are provided for rapidly changing these valves ; platforms and ladders give access to the flange bolts, heels are provided to accommodate jacks, so that the flanges on the main can be sprung apart, and a trolley-way above allows the incoming valve to be hung in readiness and the dismantled valve to be speedily withdrawn. The burners have individual air fans, the speed of which is regulated by automatic control to correspond with the gas pressure.

Besides the usual pyrometers for hot-blast and chimney-gas temperatures, thermocouples are fitted in the domes of the stoves, so that the flame temperature of the burning gas may be kept below a predetermined figure, thus avoiding spalling of the dome brickwork and the consequent blocking of checker passage-ways. To limit the temperature, excess air or combustion is introduced, and the increased heat-carrying medium nearly completely counteracts any loss of efficiency.

A Bristol hot-blast temperature regulator is installed in the mixer main, so that " straight line " temperatures will automatically be maintained. The cold-blast valves have pilot valves to equalise the pressure before opening, and the blow-off valves discharge into the chimney flues.

The whole of the stove equipment is hand-operated though designed for quick changes. Mechanical changing received full consideration, but it was adjudged an unnecessary elaboration. To save five or six minutes of the " on gas " time can be offset by burning about the same total quantity of gas at a slightly increased rate ; no labour cost can be saved, and human errors are negligible. On the other hand, mechanical equipment entails much higher capital cost and corresponding maintenance.

Gas Cleaning.

The four gas uptakes at the furnace tops rise to a considerable height above the platforms before the connections to the downcomers are taken off. Two uptakes have sealed tops, and two are surmounted by explosion valves designed to minimise the possibilities of ejecting solid material. The downcomers lead to a plain expansion-chamber dust-catcher. The dust-catcher is placed alongside the stove platform.

The dust-catcher is surmounted by relief valves, and the lower cone terminates in a dust valve. The dust will normally be discharged through a Vreeland pug-mill, in which it is mixed with water, and the insufferable nuisance of hot flue-dust blowing around the plant will be avoided

The gas is wet cleaned. It passes from the dust-catcher through a Freyn pre-cooler, where, under sprays, the temperature is reduced to nearly that of the cooling water, and where much of the heavier dust is extracted. Thence, through a manifold and three water seals, the gas enters the Theisen disintegrators, two of which are normally in operation, with a third as spare. The disintegrators are of the non-pressure type, with a capacity of 30,000 cub. ft. per min. each, and the dust content is reduced to 0·01 gr. per cub. ft.

The gas is discharged into the clean-gas system via moisture eliminators, in which entrained moisture is extracted. Valves at each disintegrator, at each stove-burner, and in the boiler main, can be closed from the cast-house, and they also close automatically when the gas supply from the furnace falls below a certain pressure. This precaution makes it impossible for air to be drawn into the gas system, and obviates the possibility of explosions.

The effluent from the pre-cooler, disintegrators, and moisture eliminators is pumped to a Dorr thickener ; the clarified water passes back to the river, and the sludge is either used in the sinter plant or is pugged with the dust from the dust-catcher. Thus, practically all the materials lost in the gases are reclaimed, reconditioned, and recharged into the furnace, the loss being confined to that 0·01 gr. that escapes in each cubic foot of clean gas, and the small amount carried over in the clarified water—theoretically some 10 lb. to 12 lb. dust loss per ton of iron.

Sinter Plant.

The examination of raw-material supplies disclosed the fact that it would be advantageous to install a fairly large sinter plant. This consists of a Dwight-Lloyd machine with an effective grate length of 51 ft. and 72 in. in width, the capacity being approximately 750 tons per day. The machine is housed in a high building alongside the high

The ore yard and blast-furnace plant.

line. Here the transfer cars, on their normal tracks, supply materials into the feed bins, whence feeder tables apportion the mixture upon a conveyer belt. In the first trommel-mixer the materials are pugged with the sludge from the Dorr thickener. The mixture is elevated by belt conveyers to a second trommel at the top of the building, from which it is poured and levelled on the pallets of the machine. Coke-oven or blast-furnace gas can be used for ignition, and a suction fan supplies the down draught, drawing the combustion through the bed of material.

The sinter is discharged over a grizzley, and accumulates in the 50-ton trailer-car ; the fines rejoin the incoming material. A very bold effort has been made to secure cleanliness in what has generally been considered an inherently dirty operation.

Hot Metal and Slag Equipment.

The same pursuit of modern economical methods that has governed the selection of other auxiliaries is reflected in the equipment for handling the products of the furnace. Pollock-type slag ladles are used, their capacities being 330 cub. ft. These ladles, by reason of their conical shape, give exceptionally easy discharge of the slag skull. The pot is tipped by means of compressed air or steam, which permits of better control than with the more primitive forms of tipping gear.

The hot metal has only a short haul of some 160 yds. to the mixers of pig-casting machine. It is conveyed in 75-ton open, short-pour Pollock ladles of extremely heavy construction. These ladles are handled by overhead cranes in the hot-metal building, and the brief period during which the iron is in the ladle renders any heat-retaining features unnecessary.

A Pittsburg pig-casting machine is installed, over which is poured week-end and surplus iron. It is of the two-strand type, capable of handling 2 tons of iron per min. The ladle-crane hoisting motions and the drive of the casting machine are controlled from a single station at the pouring end of the machine. The chief feature of this type of casting machine are the facilities for rapidly changing the moulds, the heavy chain parts of special steels with lubricated rollers, and the enclosed oil-bath driving gears.

No sand beds will be required, cleaner pig can be obtained, and so much furnace labour can be dispensed with. The only operating labour required on each of these furnace plants, after the materials are in the bunkers, will be :—

1 Foreman.	1 Slagger.
1 Stove tender	1 Helper.
1 Keeper.	1 Scale car operator.

The remaining personnel will be maintenance men, those in charge of auxiliaries, clerical staff, and superintendents.

Fourth Report on the Heterogeneity of Steel Ingots,

THE work of the Committee on the Heterogeneity of Steel Ingots has continued without intermission since 1924, and results of its investigations have been presented at intervals in the form of reports. The first and second reports, which were presented by the Committee in 1926 and 1928, were exploratory in character and contained a detailed study of a large number of ingots, which were chosen as representative practice. In addition, the influence of the mould upon segregation was discussed in the second report. Several factors having a controlling influence upon the practical problems of the investigation were considered in the third report. In the fourth report, which was presented at the recent meeting of the Iron and Steel Institute, previous work has been linked together ; but the Committee feels that an exhaustive analysis of the experimental results of the investigation, in the light of theoretical researches, is not yet possible.

A further 27 ingots have been studied, with the object of elucidating certain aspects of heterogeneity revealed by the preliminary work carried out during the first four years. Results from this investigation, which are given in section 1, indicate that the heterogeneity is determined by the manner in which the casting temperature, rate of pouring, degree of deoxidation, and conditions of chill react upon the physico-chemical mechanism of selective freezing and any mechanical movement of the liquid steel which may take place, and that, in turn, the balance between these two mechanisms determines the character of the heterogeneity which results. In regard to the influence of elements in their tendency towards segregation, results indicate that both copper and arsenic exhibit a considerable tendency to segregate, which, in view of the possible effect of these elements upon the corrosion of structural steels in which they are present, is of importance.

A brief account of the hydrogen-reduction method for the determination of oxygen in steel is given in section 2, together with a discussion of the oxygen in the oxygen-bearing silicate inclusions disseminated throughout the ingot. A new feature of the investigation is considered in section 3, which deals in greater detail with the non-metallic silicate particles, their distribution, and their composition. The principles underlying the manufacture of rimming steel have been studied in detail, and section 4 is devoted to this subject. The fundamental principles which govern the character of the blowholes that are formed in rimming steel ingots constitute a complex problem, and the Committee state that in the present state of knowledge no satisfying explanation of the phenomena associated with this type of ingot can be regarded as established.

The report of a sub-committee appointed to study the accuracy of pyrometric measurements at steel-making temperatures, is given in section 5. This report deals with the calibration of the instruments, and full details of much experimental work give a clear indication of the accuracy with which temperature measurements on molten steel may be made, and the precautions which must be taken to ensure this accuracy. In addition, the thermal history of several ingots during the period immediately following casting is recorded, and throws considerable light on the separation of the ingot from the mould, and the discontinuity in the transference of heat across the ingot-mould boundary.

The study of ingot moulds, which was discussed in the second report, has been further elaborated from the standpoint of the physical characteristics of the mould's material. This work was undertaken by the British Cast Iron Research Association, and is given in Section VI. Experience has shown that it is virtually impossible to correlate the mould life with the chemical composition and the results of this investigation support this contention, which indicates that the physical properties are in part determined by the structure, which is governed partly by the conditions of melting. The thermal conductivity values of ingot-mould irons are also discussed in this section, and investigations show that these are lower than those usually obtained from grey irons of similar compositions and structures, cast under ordinary foundry conditions, for engineering and other castings. This diminution in the heat-conducting property is stated to be due to the nature of the irons, which are lacking in denseness and are of a more open nature than normal grey-iron castings.

A development of the mathematical treatment of the problem of the distribution of the temperature in the cooling ingot, introduced in the third report, is given in Section VII. In this section the case of a semi-infinite mass of steel bounded by a mould of finite thickness is developed to take into account the effect of preheating the mould, and the modifications introduced by a layer of scale on the interface between ingot and mould, and the formation of an air gap.

The early work, given in the first report, proved that the formation of ghosts and segregated areas in steel resulted from physico-chemical laws, and that the manner and extent of such heterogeneity depended largely on the mass of the ingot and the condition of chilling. Later work, given in this present report, indicates that the presence of non-metallic particles and ghosts in the ingot is largely governed not only by the process of manufacture but also the conditions of melting and refining in the furnace and, in particular, the condition of the finishing slag at the moment of tapping, and the manner in which deoxidants are added.

The experimental programme carried out during the past two years illustrates, in addition, the effect of the temperature of the metal, the size of nozzle, the rate of teeming, and the choice of deoxidants upon the heterogeneity of the ingot, and the position is now reached at which it is possible to predict and control with a certain degree of precision the segregation associated with even the best ingots produced at modern works.

Magnesium as a Structural Metal

THE metal magnesium is now engaging wider attention in the metal-working industry, said Dr. John A. Gann, of the Dow Chemical Co., at a recent meeting of the American Institute of Mining and Metallurgical Engineers, partly because of a considerable reduction in price, and also because of progress in its metallurgy and heat-treatment. The use of magnesium powder caused the start of the industry responsible for its production in America, and then the demand extended because of the importance of magnesium as a deoxidiser in the field of nickel and nickel-alloy metallurgy. The use of 0·1% of magnesium is sufficient to make these metals completely malleable and easily workable.

Magnesium is an essential constituent of many alloys, such as aluminium and zinc, being present up to 2% in high-strength aluminium alloys, both cast and wrought, especially those whose properties are improved by heat-treatment. About 0·1% improves the stability of die-cast zinc alloys to withstand hot humid atmospheres. Important developments, however, lie in the use of the ultra-light magnesium alloys as structural materials, since the pure metal, although only two-thirds the weight of aluminium, is deficient in strength. The development of valuable high-strength alloys containing from 2 to 8% of aluminium, with small amounts from 0·15 to 0·4 manganese, constitutes one of the noteworthy contributions to modern metallurgy. Numeric l values of some of the sand-cast and also wrought and heat-treated alloys are given in the subjoined table, from which it will be seen that in some cases the tensile strength and hardness have been approximately doubled as compared with the pure metal, and the yield-point increased over six-fold. All these alloys are characterised by a high ratio of fatigue endurance to weight. Special alloys have also been developed for such specific purposes a high thermal conductivity, and others for resistance to salt-water corrosion, whilst all of them are free from intercrystalline corrosion.

The methods adopted in casting, heat-treating, and mechanically working—*e.g.*, extruding these new alloys—have now been advanced to a stage where these operations are conducted on a commercial scale. Castings in sand, permanent moulds, and die castings are readily made. Standard sizes have been fabricated to most of the standard sizes of rods, angles, and other shapes. Easy in machining is a considerable asset in the finishing of articles, and final assembly is done either by rivetting or welding by gas or electric spot.

TABLE OF PHYSICAL PROPERTIES OF MAGNESIUM ALLOYS.

Material Condition.	Yield Point, Tons per Sq. In.	Tensile Strength, Tons per Sq. In.	Elongation, % in 2 in.	Brinell Hardness. % in 2 in.
Magnesium—				
Cast	1·1	8·5	10	35
Extruded	5·0	12·5	8	38
6% Al 0·25 Mn—				
Cast	3·5	13·5	12	50
Wrought	10·0	19·5	11	58
7% Al 0·4 Mn—				
Cast	5·2	10·7	5	51
Cast and Ht. Tr.	6·0	14·3	8	51
Extruded	13·5	20·5	12	58

In the practical applications already tried are such articles as crankcases, housings, wheels, and the like, sheet metal being used for the construction of seats and tanks. One of the largest constructions yet attempted is a 50-ft. trailer, which weighs only 4,180 lb. as compared with about 8,700 lb. for similar steel trailer. Improved operation is due to increased acceleration and braking speeds, higher travelling speed, lighter and cheaper motor power, and increased pay load.

Correspondence.

The Editor, METALLURGIA.

Dear Sir,—There have been suggested several methods of getting rid of gas bubbles in molten steel, and there are thousands of papers and books dealing with the best methods of preventing segregation of impurities in steel ingots.

It occurs to me that there might be simple methods which are worth their while to try in this direction, and which, very probably, may lead to a certain degree to the desired results.

The first method I suggest is to apply vibration to the mould when it is just filled and the metal is still hot. The force of vibration should be the maximum possible, but such as not to disturb the setting of the mould. By analogy with the effect of shaking or vibration on granular material to the surface must come all foreign matter—*i.e.*, the gravity of which is different from the main body. Certainly the temperature limits, the size of ingots, the way of pouring must be considered when applying the vibration, the frequency of which must also suit conditions.

As an alternative the vibration can be applied to the steel ladle itself, when greater forces may be utilised for periods consistent with the kind of metal and its temperature.

The second suggestion has its origin in the practice of trepanning or piercing the core of a ready-made ingot.

The segregation of impurities on the core axis may start immediately the metal is poured, then a simple method may help to clean the casting. If, when the steel is still hot, whether in the mould or in the ladle itself, a tube is inserted in the centre of suitable dimensions made of heat-resisting and non-scaling material and preliminarily heated, this tube is bound to separate the "inner core," and by tight closing of the top end of the tube the hot metal can be withdrawn up to a height of, say, 60 in., the metal itself being hot enough to make up the deficiency in the mould either from the head or from the central pouring mould in bottom casting.

As an addition to the above stated, the steel and its impurities have different specific gravities; would not, then, rotation of the molten mass set up centrifugal forces which would bring a certain separation of metal and impurities in the ladle?

The Fuel Research Laboratory at Greenwich demonstrated this not long ago quite forcibly, although on a different occasion and with different materials (water and lead oxide).—Yours, etc.,

B. SHEYNIN.

Moscow,
May 3, 1932.

[Our correspondent makes some interesting suggestions for preventing segregation of impurities in steel ingots and the removal of gas. It is very questionable whether any of these methods have been tried, and if any reader has any information on the subject or is willing to reply to Mr. Sheynin, we shall be pleased to communicate information to him. As correspondence on the subject may be of general interest, we shall publish further reference to this letter in the June issue.—Editor.]

METALLURGIA

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

WILL TARIFFS RESTORE CONFIDENCE ?

CONSIDERABLE efforts have been made to re-establish the iron and steel industry on a firmer competitive basis, but lack of confidence, associated with a world-wide depression, has undoubtedly retarded development. In view of the fact that the repeated demands of a very considerable section of this industry have met with greater support, by the imposition of a defensive tariff, the added sense of security should, it would appear, give that degree of confidence likely to enable this basic industry to recover its normal productive position among the nations of the world. But will it do so, and to what extent will the imposition of tariffs influence the industry in giving more favourable consideration to contemplated schemes for modernising plant ?

While the answers to these question are difficult because of complex problems arising as a result of the departure from what has been established practice in this country for the last eighty years or so, many manufacturers consider that a definite spurt forward will be experienced. It will be appreciated that very large quantities of Continental material have been placed in stock in this country, and it may be months before the real condition of the market is ascertainable. The tariffs, meantime, being temporary, create, as can be understood, a sense of uncertainty, and the Chancellor of the Exchequer does not simplify the position by making it perfectly clear that the Government will insist upon efficiency in the industry as an essential factor in the granting of a permanent tariff.

None appreciates the need for greater efficiency more than the manufacturers, but with exceedingly low outputs, and no degree of security in the home market, in many cases it has been impossible to embark upon extensive schemes of reorganisation. Schemes that are contemplated involve a considerable expenditure of new capital, and in the present depressed state of the industry, with the degree of uncertainty that still prevails, further development is not a sound commercial proposition. A good deal of reorganisation has, nevertheless, been effected, and substantial economies both in production and sales organisation have been secured. The frequent accusations of inefficiency made against British manufacturers, which were investigated by a Committee appointed by a Royal Commission, were proved to be inaccurate, and much development work has been in progress since that time.

Realising the complexity of the iron and steel problems, and desiring to convey opinions of those intimately associated with the industry regarding the influence of tariffs in restoring confidence and creating an incentive to proceed with reorganisation schemes, we have been in communication with prominent steelmakers for expressions of their opinions. In many instances our correspondents frankly confess their inability to give a reasoned opinion on the matter ; they consider that the forces working outside those exercised by tariffs are so numerous and complex that they prefer to remain silent. Others, on the other hand, though it is too soon to speak from experience, are convinced that new possibilities are opened for the resuscitation of the industry. Thus, Mr. John Craig, managing director of Colvilles, Ltd., is of the opinion that once a proper system of tariffs is definitely agreed upon and made more or less permanent, there would be marked development in carrying out any necessary improvements, so as to enable the British steelmaker to supply the material which heretofore has been purchased from the Continent.

The influence of a tariff in improving the condition of the industry is emphasised by Mr. B. Talbot, managing director of the Cargo Fleet Iron and Steel Co., Ltd. He states that the future prospects of the iron and steel industry depend upon whether the permanent tariff is sufficiently protective. If it is, then, undoubtedly, its effect will be good, as confidence will be established by the knowledge that this great basic industry is no longer to be subjected to the dumping of foreign materials at prices bearing no relationship whatever to their economic values. The industry's difficulties will not, however, end as a result of the tariff. The burden of taxation must be lessened, and it is to be hoped that the Government will exercise the most rigid economy in the national expenditure, so that when a trade revival occurs, substantial reliefs can be given to industry to ensure it being in a position to successfully compete in the markets of the world.

The importance of the iron and steel industry from a national standpoint is emphasised in the recommendations of the Advisory Committee on Tariffs, of which the following is an extract :—" We are satisfied that the maintenance of a prosperous iron and steel industry in the highest degree of efficiency is essential to the economic progress of this country, while from the point of view of national security it must still be regarded as vital."

The iron and steel industry in this country is making every effort to keep pace with modernisation, and, provided it receives from the Government the treatment which its importance merits, we can look forward to the time when the industry will again be on a sound, prosperous, and competitive basis. Patience, however, must be exercised, for progress will necessarily be slow, as, unhappily, we have not yet reached the end of the great world depression.

No less assured is the opinion of Mr. W. Benton Jones, chairman of United Steel Companies, Ltd., who considers that the decision of the Tariff Committee to protect the iron and steel industry against unfair competition from abroad cannot but gratify those engaged in the manufacture of iron and steel in this country. The foreign competition experienced during the last few years has inflicted grave loss on the industry, but in spite of every effort to demonstrate the necessity for checking the dangerous menace, no assistance was given and no hope of assistance appeared in sight. The temporary duties now imposed will stimulate confidence, and the intention of the Tariff Committee to give to the industry the protection which in the interest of the country it requires will encourage all engaged iron and steel manufacturers to believe that the tide has now turned and to prepare for greater employment.

Sir William J. Larke, K.B.E., Director of the National Federation of Iron and Steel Manufacturers, has very clear views on the question, and asserts that the application of tariffs to the iron and steel industry is an essential condition precedent to the revival of the industry under present world conditions. He considers that the distribution of the products of industry at prices below the cost of production, characteristic of the present depression, can only involve the industrial communities concerned in

ultimate bankruptcy. Steps must therefore be taken by various means to raise the world price level of commodities and at the same time to ensure that competition in this market at least is legitimate in character in that it is based on efficient production and not on the dissipation of capital assets.

The British industry, when its position is consolidated in the home market, and it is able to organise its production on an economic basis, will undoubtedly be able to improve its competitive position in the world markets, and through Imperial and international co-operation ultimately achieve a prosperous, and it may be reasonably anticipated, an expanding future. This, however, requires a continuous volume of demand which can only be obtained under tariff conditions and by the closest co-operation between producers and consumers.

These results cannot be obtained immediately or without a great deal of effort in the development of a long-range policy requiring the highest attributes of industrial statesmanship. Immediate sacrifices for future security and prosperity may be demanded, but there is every reason to believe that the industry as a whole will rise to the height of a great opportunity. It recognises its responsibilities as one of the important bases of our national industrial economy, and will make every effort through a policy of co-operation and efficient development, to contribute to the revival of the industry generally, and the solution of the all-important unemployment problem.

It cannot, however, be too strongly insisted that industry in addition to tariffs requires relief from the burdens of taxation through a reduction of our national expenditure, as an equally essential condition precedent to its permanent recovery.

It will be appreciated that the prospects of the iron and steel industry, like the prospects of every other industry in the country, are bound up with world trade and depend upon the recovery in world trade as much as, even if not more than, any other consideration. While it is early to express any view as to the effect of the actual duties imposed, which are of a temporary nature, the reception given to them, as indicated by these responsible representatives in the industry, makes it clear that protection of this nature is in the national interest.

It is particularly gratifying to note that more concrete evidence of the effect of tariffs on the iron and steel industry is indicated by possible developments in South Wales. Mr. Lionel D. Whitehead, chairman of the Whitehead Steel Works, Newport, has stated, according to *The Times*, that the new mill which was put into commission a year ago would operate a double shift immediately after the Whitsun holiday. These works have at present an order for 5,000 tons of tube strip for Russia. Tariffs, it is frankly stated, have enabled the company substantially to open up trade in directions to which the Continent in recent years have sent almost exclusive supplies in this respect. There are prospects, if trade continues to expand, that this double shift will be permanently established. This company has already decided to convert an auxiliary bar mill into a completely separate unit, and embody in it a specially designed double-strand straight continuous wire rod mill. With the completion of these extensions the company will possess a wide range of modern high-capacity mills capable of an output of 4,000 to 5,000 tons of light sections per week. This is distinct evidence of greater confidence in the industry, and as the stocks of materials now held diminish and the effects of the tariff become more apparent, the increasing demands made upon manufacturers will involve plant developments in an effort to improve efficiency.

Foundrymen's Conference at Newcastle.

THE twenty-ninth annual conference of the Institute of British Foundrymen, to be held in Newcastle-on-Tyne, June 8–10, is the third annual conference to be held at this centre—the last having been held eight years ago. The conference will begin at 9-15 a.m. on June 8, in the Lecture Theatre of the Literary and Philosophical Society, in Westgate Road, by a civic welcome from the Lord Mayor of Newcastle, Alderman J. G. Nixon, J.P., and addresses of welcome from the President of the Newcastle and Gateshead Chamber of Commerce, and the Principal of Armstrong College. After the annual general meeting of the members, various presentations will be made, and Mr. Victor Stobie, the president-elect, will be vested with the chain of office by the retiring president, Mr. A. Harley.

In addition to a number of papers on interesting subjects which are to be submitted at the technical sessions to be held during the mornings of June 8 and 9, arrangements have been made to visit various works in the neighbourhood. These will take place during the afternoon, and will include visits to the North Eastern Marine Engineering Co., Ltd., Wallsend; Messrs. A. Reyrolle and Co., Hebburn-on-Tyne; Sir W. G. Armstrong Whitworth and Co. (Iron Founders), Ltd., Gateshead: the Priestman Collieries, Ltd., Teams; the Consett Iron Co., Ltd.; Messrs. Armstrong Saurer Commercial Vehicles, Ltd. Scotswood; and Messrs. Smith Patterson and Co. Ltd., Blaydon.

FORTHCOMING MEETINGS.

THE IRON AND STEEL INSTITUTE.

May 17. At the Royal Metal Exchange, Swansea, "Fourth Report of the Committee on Heterogeneity of Steel Ingots." "The Determination of the Porosity of Tin Coatings on Steel," by D. J. Macnaughton, S. G. Clarke, and J. C. Prytherch.

May 23. Jointly with the Cleveland Institution of Engineers, at the Cleveland Institute, Middlesbrough. "Blast-furnace Engineering," by Major W. R. Brown. "Recent Improvements in the Greenawalt Sintering Apparatus," by J. Tornblad.

May 24. Jointly with the Sheffield Metallurgical Association, at The University, Sheffield. "Fourth Report of the Committee on Heterogeneity of Steel Ingots." "The Properties of Some Silico-manganese Steels," by G. Burns. "The Heterogeneity of a Sand-cast Steel Ingot," by A. Kriz. "Some Experiments on the Nitrogen Hardening of Cast Iron," by J. E. Hurst. "The Influence of the More Common Elements in Inhibiting Needles in Nitrogen-rich Steels and Arc-welds," by L. W. Schuster. "The Theory and Practice of Nitrogen Case-hardening," by A. Fry.

THE INSTITUTE OF BRITISH FOUNDRYMEN.

June 7–10. Annual Conference, to be held in the Lecture Theatre of the Literary and Philosophical Society, Westgate Road, Newcastle-on-Tyne. Following the general meeting, technical sessions will be held at which the following papers will be discussed:—

June 8 (Morning). *French Exchange Paper.* "Some Notes on Moulding and Pouring Practice," by J. Pillon. "Quantity Production of Grey-iron Castings," by J. O'Sullivan, of Henry Ford and Son, Ltd., Cork.

June 9 (Morning). *Session A.* "Hardening Cast Iron-hardened and Tempered and Nitrogen-hardened Cast Iron," by J. E. Hurst. *American Exchange Paper.* "High-test Cast-iron Developments in the United States," by R. S. MacPherran. "Distortion and Camber in Castings," by F. Longden. *Session B.* "Ferrous and Non-ferrous Metals in the Foundry," by W. Rosenhain, D.Sc., F.R.S. "Some Lifting Considerations in a Jobbing Steel Foundry," by F. J. Hemming. A résumé of the work of the Malleable Iron Sub-Committee of the Institutes Technical Committee.

June 8 (7 p.m.). Annual Banquet and Dance at Grand Assembly Rooms, Barras Bridge.

AMERICAN SOCIETY FOR TESTING MATERIALS.

June 20–24. Annual Meeting, Atlantic City.

ELECTROPLATERS' AND DEPOSITORS' TECHNICAL SOCIETY.

May 18. "The Adhesion of Electrodeposited Nickel to Brass," by A. W. Hothersall, M.Sc., at the Northampton Polytechnic Institute.

June 15. Annual Election of Committee and Officers.

Melting Grey Iron in the Electric Furnace.

THE use of the rocking indirect arc type electric furnace, first brought into commercial use during the world war, has been extended to a diversity of applications, not only for melting and processing both ferrous and non-ferrous metals and alloys, but for certain chemical and other special operations on both metallic and non-metallic materials, where the characteristics of this type of furnace have been found advantageous. These applications were described and discussed by Messrs. A. E. Rhoads and C. H. Morkey at the recent general meeting of the Electrochemical Society. This type of furnace, which carries two horizontal electrodes and is equipped with automatic mechanical rocking, permitting a controlled

TABLE I.

PROPERTIES OF ULTRA HIGH STRENGTH CAST IRON.

No.	Ultimate Tensile Strength.		Transverse Strength.		Deflection.		Total C %	Si %	Mn %	Mo %
	Lb./Sq. In.	Kg./Sq. Cm.	Lb.	Kg.	In.	Mm.				
*1	67,500	4,745	6,670	3,028	0·107	2·7	2·04	2·08	0·56	0·50
2	64,200	4,513	6,175	2,803	0·118	3·0	2·65	2·11	0·69	0·44
3	63,050	4,432	6,280	2,851	0·127	3·2	2·26	2·39	0·50	0·50
4	62,800	4,415	5,112	2,321	0·073	1·9	2·36	2·05	1·15	nil.
**5	—	—	4,311	1,957	0·348	8·8	2·57	2·23	0·60	0·50
6	—	—	3,929	1,784	0·310	7·9	2·61	2·15	0·55	0·50
7	—	—	3,897	1,769	0·292	7·4	2·63	2·24	0·58	0·44

* Tests illustrated by No. 1 to 4, inclusive, are based upon 1·25 in. (3·18 cm.) arbitration bar, broken on 12 in. (30·5 cm.) centres, and the tensile specimen machined from a section of this bar.

** Tests illustrated by No. 5 to 7, inclusive, were made on 1·2 in. (3 cm.) bar broken on 18 in. (45·7 cm.) centres.

stirring of the charge during heating, possesses unique features which for melting and superheating operations are highly desirable and in certain instances indispensable. Its characteristics have brought about numerous applications and increasing varieties of products. In the ferrous field this type of furnace is being increasingly applied to grey iron, steels, malleable and heat-treated irons. Grey iron produced in the rocking indirect arc electric furnace, for instance, is dense, close-grained, thoroughly uniform, and of exact, predetermined composition. The automatic stirring of the bath provided by the rocking action during the melting and superheating periods ensures homogeneous metal without localised overheating.

The furnace is commercially employed in producing grey iron by three distinctly different methods: cold melting, duplexing, and by synthesising from steel scrap. In addition to producing irons of high tensile strength, several indirect arc furnaces are engaged in producing very soft, highly machinable irons, where density and uniformity are of value; others are used for the economical production of alloy irons of various types; still others are used to reclaim low-priced steel scrap and to produce from this material grey iron of unusual qualities. Several installations of this type of electric furnace are engaged in producing cast iron possessing very high tensile strength values as cast, with no subsequent heat-treatment. The properties and compositions of a group of grey irons possessing unusually high strength are shown in Table I. The data were obtained from routine checks in regular commercial production.

Iron of this type is used to replace steel and malleable castings in some instances, and to replace steel forgings in others.

Readily Machinable High-test Cast Iron.—A large portion of the grey iron produced in these furnaces is of a type that has moderately high strength and possesses excellent machining qualities. The properties and compositions of a group of these irons is shown in Table II.

This type of furnace possesses advantages for the production of dense soft iron. The ability to control the analysis within close limits, enabling a properly balanced composition being obtained; stirring of the metal by the automatic rocking action, eliminating silicon segregation; thorough degasification and deoxidation; flexibility, and the ability to produce, under accurate control, metals of different compositions from a base heat.

Table III. illustrates the use of the indirect arc furnace in the production of soft and medium iron. The original heat in both cases was 2,000 lb., all of which was brought to the composition given in the first column. The desired quantity of metal was removed, and the remainder adjusted

TABLE II.

READILY MACHINABLE HIGH TEST CAST IRON.

Example No.	Ultimate Tensile Strength.		Transverse Strength.		Total C %	Si %	Ni %	Cr %	Mo %
	Lb./Sq. In.	Kg./Sq. Cm.	Lb.	Kg.					
1	56,000	3,937	6,250	2,838	3·00	2·00	—	—	0·50
2	52,300	3,677	7,140	3,242	2·70	1·96	—	—	—
3	46,100	3,241	6,020	2,733	2·80	1·88	1·50	0·50	—
4	45,065	3,168	5,120	2,324	2·85	1·97	—	—	—
5	42,180	2,965	3,886	1,764	3·05	2·03	1·45	—	—

NOTE.—Transverse strength data above were obtained from the 1·25 in. (C·18 cm) bar with 12 in. (30·5 cm.) centres.

by suitable additions of coke and ferro alloy to the composition given in the second column under each heat. A quantity was poured, and the remainder again adjusted to another composition, etc. The foundry from which the data in Table III. were obtained has made as many as five different compositions of iron from a single-base melt in a 1½-ton indirect arc furnace. In this type of furnace the melting loss of heat, corrosion-resistant, and special high-alloy irons, is unusually low, and averages less than one-half of 1% on such oxidisable elements as chromium, vanadium, and tungsten. Therefore, it is possible, with this furnace, to realise substantially full recovery of all alloys contained in the foundry returns. The indirect arc furnace is extensively used for the following irons: Ni-resist, which is a nickel-chrome-copper cast iron used for corrosion and heat-resistant parts; Nomag, another non-magnetic iron, high in manganese and nickel, used for electrical parts; and various nickel-chrome combinations used for heat-resistant parts.

TABLE III.

ILLUSTRATING CONTROL OF COMPOSITION.

	Heat No. 1.				Heat No. 2.		
Metal in furnace: Pounds	2,000	1,300	1,000	300	2,000	1,300	600
Metal poured: Pounds ...	700	300	700	300	700	700	600
Finished carbon, %	2·88	3·00	3·08	3·40	3·10	3·42	3·37
Desired carbon, %	2·90	3·00	3·10	3·40	3·10	3·40	3·40
Finished silicon, %	1·93	1·97	1·99	3·06	2·00	2·00	3·07
Desired silicon, %	1·90	2·00	2·00	3·00	2·00	2·00	3·00

TABLE IV.

COLD MELTING COST.

Item.	Cost per Ton.
Power: 550 kw.-hr.	$6·87
Electrodes: 8·5 lb. @ 16·5c.	1·40
Refractories	1·00
Labour	1·00
Miscellaneous: Maintenance, water, etc.	0·25
Conversion cost	$10·52
Cost of borings	5·00
Total cost per ton charged	$15·52
Recovery, 97%	
Total cost per ton poured	$16·00

The low-carbon Ni-resist metals are superior in strength and structure to those of high-carbon content. They are easily and accurately produced in the indirect arc furnace, and the freedom from slags and oxidation ensures obtaining the desired composition with the proper carbon-silicon ratio, and without suffering the temperature drop incident to ladle additions.

These irons show an ultimate tensile strength of from 30,000 lb. to 35,000 lb. per sq. in. (2,109 kg. to 2,460 kg. per sq. cm.), which is approximately 25% above that normally obtained from the higher carbon Ni-resist irons.

Most of the types of grey iron referred to can be made by any of three processes: (1) Straight cold melting; (2) duplexing cupola-melted iron; or (3) synthesising from steel scrap. Such factors as: Required production per furnace unit per day, and local values of materials, determine which process is to be used.

(*Continued on page* 32.)

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part XIII.—Finish Rolling.

In this article the finish-rolling operations in the production of aluminium flat sheet and coil are discussed. The general principles of finish rolling are dealt with first, and then details of the practice employed in the manufacture of grey plate, bright flat sheet, and coil are given. Lubrication of the metal on the finishing passes is considered. Pack rolling in the production of light-gauge flat sheet is described. Drafts and number of passes in reducing to the finished gauge are discussed at some length. The essential differences in the finish rolling of flat-sheet stock as compared with coil are emphasised. The present discussion is concerned for the most part with the practice employed in finish rolling commercially pure aluminium and the softer alloys, but some information is also given as applying to hard alloys, such as duralumin. Finally, brief consideration is given to recent, and probable future, tendencies in rolling methods as influenced by consumer demands for close gauge tolerances, necessity for decreasing labour costs of finish rolling, and other factors. In this connection some experiments carried out to determine the feasibility of rolling wide aluminium strip on four-high continuous mills are described.

THE final passing made in reducing aluminium sheet and coil stock, after roughing, to the desired gauge or thickness is referred to as finish rolling. While the primary object of finish rolling is reduction to gauge, at the same time special surface finishes may be imparted to the material on the finishing passes. This latter applies more particularly in the production of flat sheet in 99+% aluminium rather than of coil or in the rolling of alloys.

In rolling to gauge, whether in the case of flat sheet or coil, it is usually requisite and essential that the material be produced of reasonably uniform thickness—both across the width and along the length. For the bulk of commercial material, the usual gauge tolerances listed in engineering specifications are good enough. The thickness tolerances allowed for aluminium and duralumin sheet, of various gauges and widths, by late specifications of the American Society for Testing Materials, have been given in the first article of this series. Generally speaking, the demands of consumers as regards close gauge tolerances have become increasingly troublesome to meet, and must eventually lead to a revision of rolling methods—*e.g.*, the use of the four-high mill for wide strip. Numerous instances may be cited where sheet users are demanding tolerances which are unnecessarily close and which can be made only at considerable extra expense by the mill when the material is rolled with conventional equipment. Also, there have been numerous instances, in the writer's experience, where consumers have specified that sheet or coil should measure "light" or "heavy" as referred to a particular gauge, and then complained, when the stock was delivered, because the material carried the normal ± tolerance for the specific thickness (and width), as referred to the nearest gauge. In some applications of aluminium sheet, notably for radio-condenser stock and lithographic plate, exceedingly close tolerances in all directions are demanded and met, but such material carries a suitable premium.

Unfortunately, the matter of surface finish is greatly overemphasised—at least in American practice,—so far as the general utility of sheet and coil is concerned. As a general proposition, the presence of minute surface defects should be, and is, of no practical consequence so far as the mechanical properties and satisfactory utilisation of the material are affected. However, consumers, in many instances, demand well-nigh perfect surfaces—if there is any such thing as a perfect, flawless surface,—and then proceed to sand-blast, paint, etch, stamp, bend, form, or otherwise mutilate such surfaces. True enough, there are sundry applications of aluminium sheet where a substantially flawless surface is necessary, or at least highly desirable. On the other hand, there are very many applications where the condition of the surface assumes relatively little importance. In any event, the surface finish (and freedom from surface flaws) required in aluminium sheet and coil products has important bearing on rolling-mill methods and practice. This is also true with respect to gauge tolerances. It will be understood, of course, that while the required surface finish may be made or spoiled on finish rolling, the presence of surface defects may be associated with almost any one of the numerous steps in the manufacturing process from the raw melting stock to packing for shipment. In a later article, detailed consideration is given to the question of defects in aluminium sheet, particularly surface flaws, and the relation of rolling practice thereto.

General Principles of Finish Rolling.

An understanding of the inherent physical characteristics of aluminium and its behaviour on finish rolling is necessary to an appreciation of the methods employed in practice, speed of operation possible, and defects which may arise in the processing. The broad principles which govern the cold rolling of metals in general apply also to aluminium, but the peculiarities of this metal must be recognised, and certain special methods of rolling and handling must be used if commercially satisfactory sheet and coil are to be produced. Aluminium can be deformed very easily at the ordinary temperature, because it has great ductility (owing to its face-centered cubic lattice), and is also relatively soft. It is, unfortunately, at the same time an exceptionally troublesome metal to deal with on finish rolling.

On account of its softness and ductility, aluminium can be worked cold with heavy drafts, and can be reduced enormously without intermediate annealings. Duralumin (and related alloys) is not, however, so easily worked, and requires intermediate annealings between passes on the way down to gauge. While the easy workability of aluminium is of great advantage in hot breaking down and in the preliminary cold slabbing and roughing operations, its softness is of considerable disadvantage in finish rolling. Various troubles may arise in rolling aluminium because of the mechanical and physical properties of the metal, and the chief difficulties encountered are listed below:—

1. Sheets readily take impressions from the rolls, and are easily marked by the rolls through jolts, transmitted from the pinions and drive.

2. Ripple marks, waves, buckles, and corrugations are readily formed.

3. Rolls may be marked on a pass due to pinch or whip in the sheet; on the next pass the roll mark is imparted to the sheet surface.

4. The metal is unusually susceptible to the influence of various factors which tend to produce uneven gauge.

5. Holes are easily punched in sheet by foreign particles.

6. The metal is easily scratched and marred.

7. On account of the relatively high coefficient of friction of aluminium against steel or cast iron, sheets tend to stick to the rolls. The friction also introduces undesirable heating effects both in the sheet and the rolls.

8. The whitish colour of the metal readily shows small surface flaws, dirt, finger-marks, and grease spots. In the case of planished sheet, the mirror-like finish serves as a sort of illuminated background which brings surface defects, scratches, and markings into sharp relief.

The relative softness of aluminium is the predominating physical influence affecting the difficulties listed above as items 1 to 6, inclusive. While the present discussion applies more particularly to finish rolling, in a general way it applies also to slabbing and roughing. Broadly, some of the difficulties of rolling, which are associated with the physical properties of the metal, more especially softness, are increased as the gauge thickness is decreased.

Flat Sheet v. Coil Rolling.—As generally practiced, the finish rolling operations on flat sheet and coil are essentially different. Two-high mills are ordinarily employed for both products. Sheet is rolled on mills having rolls of, say, 48 in. to 120 in. in face length, and coil is rolled on mills having rolls of about 12 in. to 36 in. in face length. Relatively narrow flat sheet may be roughed in the form of coil on coil mills, cut to length, flattened, and then finished to gauge on flat-sheet mills. Planished or grey-plate finishes may be imparted to the stock on rolling flattened-coil stock to gauge on flat-sheet mills. So-called flattened coil is made by running stock to gauge on a coil mill, followed by shearing to lengths, and then flattening in a roll leveller. In this case, the regular coil surface finish is obtained.

One important difference in the finish rolling operations on flat sheet as contrasted with coil is presented in the number of passes required in running from the roughed stock to final gauge. Thus, flat sheet is finished with a great multiplicity of passes, say, 25 to 75, while coil is rolled to gauge with about two passes, or with a few at most. In the case of sheet, a large number of passes is necessary to work out the "centre" of the stock, obtain uniform gauge, promote flatness, and yield the required surface finish. This is explained more fully under the sub-heading "Passes and Drafts," below. Flat-sheet aluminium may be produced with at least three surface finishes, imparted on finish rolling—viz., grey plate, commercially bright, and extra bright. This is quite aside from special surface finishes produced by etching, sand blasting, scratch brushing, or other treatment after rolling to gauge. Coil, on the other hand, is ordinarily made in only one surface finish. In American practice, using cast-iron rolls, coil is rolled on wet (lubricated) roll surfaces, and sheet is rolled on substantially dry roll surfaces. Both the surface finish obtainable and the quantity of lubricant required are dependent on the composition of the rolls, whether chilled cast iron or forged alloy steel.

In the case of flat sheet, gauges lighter than about No. 20 (Brown and Sharpe) are rolled in pack. Coil is not rolled in pack. There are several reasons why the lighter gauges (20- to 34-gauge) in flat sheet are to be pack rolled. In the first place, with a single sheet, there is insufficient thickness, or body so called, in light gauges, so that uniform pressure can be exerted by the rolls across the width. This refers to rolling on conventional two-high mills equipped with large rolls which are ground with the usual crowns. Hence, unless rolled in pack, uniform gauge cannot be obtained. Furthermore, if sheets were rolled singly, at about 26-gauge (depending on the condition of the mill, the symmetry of the rolls, their alignment with respect to each other, and the grinding), the rolls must be very nearly on contact in order to roll to gauge. Hence, it might not be possible to reduce to final gauge unless the material were run in pack, or at any rate the number of passes required would be unduly increased. Finally, whether rolling singly or in pack, it is not practical to make the roll set too scant, because of the danger of pinching, working out the heavy centre too fast, or working the stock to gauge before it has attained the desired flatness. In order to overcome the adverse conditions surrounding the production of light-gauge flat sheet and obtain uniformity of gauge, it is necessary to roll in packs of two or more sheets. Table III. of the previous article of this series[1] lists the number of sheets to be rolled per pack for different gauges. The number of sheets per pack is increased with decrease in the thickness of the individual sheets. Roughly, the average total thickness of the pack at the finish may be about 0·05 in. It may be somewhat thicker with very light gauges.

Another important difference in the finish rolling of flat sheet as compared with that of coil is presented in the degree of skill required for the two products. The finish rolling of flat sheet is more or less of an art, or at the least demands a considerable degree of experience and skill. Good coil, on the other hand, can be rolled by relatively unskilled labour. Further, there is a great deal more handling required in the rolling of flat sheet as compared with that of coil. For these reasons the direct labour costs of flat-sheet production compare unfavourably with the corresponding costs of coil rolling. This disparity in costs, and consequently, to some extent, selling prices of sheet and coil, has led to increased use of coil and flattened coil. Also, economic considerations and consumer requirements have lately focused the attention of mill operators on the advisability of producing strip in sheet widths. This latter, as is well known, is a recent development in sheet steel practice. Fairly wide aluminium sheet can be rolled to close gauge tolerances on four-high mills at considerably less cost than on ordinary two-high mills. A *resume* of some recent experiments carried out to determine the feasibility of rolling wide aluminium strip on four-high continuous strip mills is given in later paragraphs of the present article.

It appears to the writer that in the future a substantial percentage of the aluminium flat sheet now produced in the bright or grey-plate finishes on two-high mills will be rolled as wide strip on four-high continuous mills. This is a logical development, and may lead to increased use of aluminium sheet in competition with sheet in other metals. Long lengths in wide strip would, of course, have to be produced from large ingots, bloomed to heavy sheet bars. Strip as delivered from the last stand of a four-high continuous mill is normally to be rolled up into a loose coil. Sheets of various sizes may be obtained from the wide strip coil by cutting off lengths, flattening the lengths in a roll leveller or sheet stretcher, and then shearing to the exact dimensions required. Special surface finishes could be imparted to sheet made from wide strip. Thus, a surface finish not unlike that of grey plate might be produced by etching or sand blasting. A surface comparable to that of bright planished sheet may be produced by polishing.

Passes and Drafts.—Broadly speaking, aluminium flat sheet is finish rolled to gauge with relatively light draft and many passes, and coil is finish rolled with relatively heavy draft and few passes. In both cases, the draft is lighter the lighter the gauge. As mentioned previously, the drafting and passing are entirely different for the two classes of products. Thus, in the case of flat sheet, the roll opening is set and a large number of passes are made, whereas with coil the roll opening is set before each pass.

[1] R. J. Anderson, "Aluminium Sheet Production, Part XII.—Slabbing and Roughing," *Metallurgia*, Vol. V., No. 30, April, 1932, pp. 202.

As regards flat sheet, this refers to the medium and light gauges. In finish rolling heavy gauges of flat sheet, two to five passes may be given after each set of the rolls. In finishing plate, the roll opening may be given a set for each pass.

TABLE I.

COMPARISON OF FLAT SHEET AND COIL WITH RESPECT TO PASSES.

Operation.	Thickness after the Operation, In.	No. of Passes.
Flat Sheet.		
Hot breaking down	0·25	*
Slabbing	0·15	5
Roughing	0·060	15
Finishing	0·027	55
Coil.		
Hot breaking down	0·375	*
Slabbing (on continuous mill; seven stands)	0·10	7
Roughing	0·045	4
Finishing	0·027	2

* Five to nine passes, depending on the size of the original ingots and the size of the hot-mill slab.

A comparison of the number of passes given in producing flat sheet and coil is shown by the data in Table I. Omitting the passes made in the hot break-down operation 13 passes were given to the stock in rolling coil of certain width to 0·027 in. thick, and 75 passes were made in rolling flat sheet of certain size to the same thickness. In passing, it is of interest to point out that, as a general proposition, certain defects tend to "roll out" with flat sheet because of the large number of passes given and "roll in" with coil because of the relatively few passes.

In the finish rolling of flat sheet there is no fixed or standard number of passes to be made, corresponding to a given finishing allowance. The number of passes required to finish properly a pair of flat sheets depends upon numerous factors, of which the following are the most important—viz.: (1) Condition of the original roughed stock, more especially as regards flatness, presence of corrugations, depth or weight of coating, and the amount of heavy centre; (2) original thickness of the roughed sheets with relation to the finishing gauge—*i.e.*, the finishing allowance; (3) the finishing gauge; (4) the size of the finished sheet—*i.e.*, length and width; (5) gauge tolerance; (6) the degree of flatness required; (7) the finishing temper; and (8) the nature of the surface finish.

Roughed sheets should be delivered to the finishing mills in proper condition for finish rolling; otherwise, it may not be possible to finish the stock satisfactorily or at best the labour of finish rolling and number of passes required will be much increased. Roughed sheets should be relatively flat and smooth and free from localised buckles and corrugations. Properly roughed light-gauge sheets are more likely to be smooth as to surface than heavy-gauge sheets, and the former can accordingly be finished with fewer passes. The latter may have large corrugations entirely across the width. If a sheet has corrugations localised in the centre, the chances are that the stock is too light in the centre. Then, in order to work the sheet to the shape of the roll, thereby producing the required flatness, it may be necessary to increase greatly the otherwise normal number of passes and roll with very light draft. This practice, unfortunately, tends to cause whip and tail splits.

A heavy coating (of particles of aluminium and aluminium oxide) on the surfaces of roughed sheets is undesirable, particularly in the finish rolling of bright and extra bright material. More passes are required to remove a heavy coating than a light one. Other complications are also introduced; these are dealt with later in this article.

The number of passes required in finish rolling flat sheet is, of course, influenced by the amount of heavy centre provided in the roughed stock. At the same time, various factors markedly affect this relation, notably the crown of the rolls and their temperature. By and large, if the correct amount of centre is provided (as determined by past experience for different widths and thicknesses and for specific crown and temperature conditions), fewer passes are required in finishing to gauge and the desired flatness than when greater or lesser amounts of centre are to be worked. Thus, if the centre is too heavy, the sheets are liable to cut through on the finishing mill with the normal roll set. In order to prevent this, the draft must be lessened and the number of passes increased. Conversely, if the centre is too light, and especially if it is lighter than the edges, then it may not be possible to roll the sheets flat at all, or at best the number of passes will have to be much increased.

In general, the greater the finishing allowance the greater the number of passes required in reducing to gauge. This refers more especially to the medium and light gauges, since with the heavy gauges and plate the draft per pass (or per few passes) can be increased within reasonable limits as desired. Of course, in practice, the finishing allowance is normally held to a minimum. As a rule, the lighter the finishing gauge the greater the number of passes required. Also, the wider and longer the sheet the greater the number of passes. More passes are necessary with lighter and larger sheets in order to secure the necessary degree of flatness as compared with heavier and smaller sheets. Uniformity of gauge is markedly affected by the passing and drafting. Smaller total ± variations in all directions are the result of rolling with very light drafts and many passes. This applies to both sheet and coil processed on two-high mills. In commercial material, gauge variations are likely to be less in sheet than in coil because of the difference of rolling practice employed for the two products.

The degree of flatness obtained in sheet is a function of the number of passes as well as of some other factors. Broadly, flatness is promoted by rolling with many passes as contrasted with a lesser number. It is to be understood that in practical work a sheet should attain the desired flatness just as it is brought to gauge. This is discussed more fully below when considering the details of flat-sheet finishing practice. Here, it may be pointed out that in finishing heavy-gauge sheet, say, up to 16-gauge, rolling too much—even one pass too much—may buckle or corrugate the sheet. In finishing light-gauge sheet, however, the greater the number of passes, within limits, the greater the degree of flatness. With a properly shaped roll, any sheet must be sufficiently worked, so that the surface conforms to the shape of the roll if the material is to be rolled flat.

More passes are required to finish sheets in a softer temper than in a harder temper. Also, the draft on sheets to finish in a soft temper should be less than on stock to finish in a hard temper. In processing soft tempers, there is danger of the sheet finishing below gauge because of its greater plasticity as compared with metal of hard temper, or the sheet may be brought down to gauge before it has been worked flat. Thus, sheets to finish in such relatively soft tempers as 2 S 2 or 2 S 4 must be given considerably more passes than sheets to finish as 2 S H (full hard). So-called dead-soft aluminium sheet (2 S O) is, of course, made by annealing hard sheet (2 S H). In regard to the effect of the surface finish, it may be said that grey plate requires fewer passes than commercially bright sheet, and this latter requires fewer passes than extra bright material.

While the foregoing discussion is concerned largely with the processing of flat sheet, the general principles elucidated apply also to the finish rolling of coil. In running coil, the stock is reduced as much as possible on each pass, but at the same time not so much as to produce uneven gauge across the width or along the length. Further, in finishing coil, the draft is reduced per pass as the thickness is reduced. This procedure is necessary because (1) the body of metal to be worked decreases progressively; (2) the relatively heavy centre must be worked out gradually; and (3) it produces more even gauge along the length of the coil. Specific details of the passing and drafting in finishing sheet and coil are given in later paragraphs.

Shape of Roll Surfaces.—In aluminium practice, mill rolls are ground to special shapes of surface, depending

upon requirements and the preferences of different operators. This applies to both flat-sheet and coil-mill rolls. Fig. 1 shows sketches illustrative of the usual shapes—viz., crown, flat, crown (upper), and flat (lower), and hollow. In some plants, rolls are ground either with crowns or flat, depending on the face length. Thus, the rolls of small coil mills, measuring 12 in. to 20 in. in face length, may be ground flat; the rolls of larger coil mills, measuring 24 in. to 36 in., may be ground with a crown of about 0·002 in. The rolls of flat-sheet mills may be ground with a crown of 0·003 in. to 0·005 in., depending on the width. At one plant, in the case of sheet mills equipped with rolls measuring 84 in. in face length, the top rolls are crowned 0·006 in., and the bottom rolls are ground flat. If rolls are ground hollow, the depth of concavity may be adjusted for the width (face length), so that on heating, when the mill is in operation, the rolls expand so as to become substantially flat as to surface.

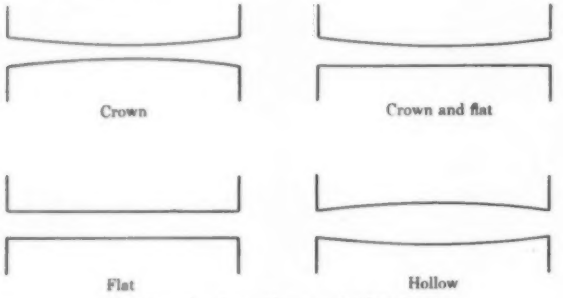


Fig. 1.—Surface Shapes of Mill Rolls.

In the case of a small coil mill operating on narrow strip, no crown is necessary, but with a large coil mill a small crown is desirable. Coil can be rolled flat on full rolls, when operating on wide metal, with greater draft and fewer passes. Slightly hollow or flat rolls are indicated for rolling wide sheet singly. Fewer passes are required with hollow rolls than with flat rolls, in order to produce sheet of the desired flatness. When single sheets are rolled on crown rolls, it is very troublesome, if not impossible, to secure the necessary flatness. On the other hand, crown rolls are indicated for rolling sheet in pack, since fewer passes are required than with flat rolls. Crown rolls are used in rolling flat sheet singly in some plants where tonnage is important, flatness being obtained by stretching on a levelling machine. This practice reduces the number of passes required in finishing to gauge. Also, sheets which are to be delivered in the dead-soft (2 S 0) temper need not be rolled flat, and accordingly may be processed on crown rolls. Annealing removes the waves and flattens sheet. It will not, however, remove buckles. Any practice which tends to reduce the number of passes in finish rolling flat sheet, but still yields the desired results, is generally advantageous.

As is understood, the shape of a roll can be changed markedly by application of, or regulation in the flow of, water to the neck. Rolls become heated when metal is passed between them, due to the friction. The heat is radiated to the air, dissipated in part to the sheets being passed, and also travels along the length of the rolls to the necks. The application of cold, running water to the necks cools the ends of the rolls, or, as it is expressed, "drives the heat to the centre." Hence, if rolls are too full in the middle of the length, for the particular width of sheet being rolled, then the flow of water on the necks should be reduced or cut off; this allows the ends of the rolls to expand more, or for the time being reduces the temperature at the middle, thereby promoting contraction, or both. If rolls are too full on the ends, water should be allowed to run on the necks, thereby cooling the ends and promoting contraction. The temperature of a pair of rolls while in operation changes more or less continually from various causes, and consequently the shape changes. Periodic regulation of the water flow is therefore necessary. As a roll become warmer the total diameter tends to increase; this affects the roll opening, and proper cognizance must be taken of this factor in adjusting roll sets. In running coil, the lubricant used has considerable effect on the shape and temperature of the rolls.

(*To be continued.*)

Standard Tests on Galvanised Wire.

THE method of testing galvanised wires by dipping samples in a solution of copper sulphate is so well known that it would hardly appear necessary at first sight to issue a Standard Specification on the subject. It is found in practice, however, that, although the general principles of the test are almost universally accepted, individual manufacturers and inspectors often introduce slight variations in the testing routine which, though apparently unimportant, have a substantial effect on the result of the test.

The British Standards Institution has now co-ordinated all the descriptions of the test given in various specifications and has published Specification No. 443, entitled "The Testing of the Zinc Coating on Galvanised Wires." This new specification states concisely, but in adequate detail, the exact procedure to be followed in the preparation of the samples, the preparation of the copper sulphate solution, and the number and duration of dips in the solution, the latter being graded in accordance with the diameter of the wire.

A feature of particular interest is the introduction of a combined mechanical and chemical test, in which the sample of wire is first wrapped round a mandrel of a specified size, is then unwound and subjected to the dipping test.

Research work with a view to finding a test which has a definite relation to practical service conditions or provides an absolute comparison between various processes of galvanising, is at present in hand. It is recognised, however, that it will still be a long time before the copper sulphate test will be superseded, and the issue of the new British Standard Specification should, therefore, prove of considerable value to both manufacturers and users of galvanised wire.

Copies of this Specification No. 443—1932 may be obtained from the Publications Department, British Standards Institution, 28, Victoria Street, S.W. 1, price 2s. 2d., post free.

Specifications for Cored and Soft Solders.

A new British Standard Specification for Cored Solder, Rosin Filled, No. 441—1932, has recently been issued. This provides for six standard sizes ranging from 8 to 16 S.W.G., and contains clauses regulating the composition of the solder and of the quality and proportion of the rosin, with provisions for the sampling of the material for examination and analysis.

Soft Solders.

Primarily in order to make provision for the incorporation of a further grade of solder, Grade K, suitable for certain classes of machine soldering, the British Standards Institution has also recently issued a revised edition of the British Standard Specification for Soft Solders. No. 219—1932. The compositions of the Grades A to J remain unchanged, though modifications have been made in some instances in the references to the uses for which the solders are primarily intended. Some additional provisions have been made in the clause relating to the chemical analysis of samples.

Copies of these Specifications (Nos. 441 and 219—1932) may be obtained from the Publications Department, British Standards Institution, 28, Victoria Street, London, S.W. 1, price 2s. 2d. *each*, post free.

The Electro-deposition of Nickel and Chromium

By J. W. Cuthbertson, M.Sc.

The introduction of chromium plating has brought about great changes in the technique of commercial electroplating ; this applies in particular to nickel plating where the demand for increased output and better quality of product has revolutionised the whole operation. The present article is devoted largely to a description of plating plant, and will be followed by short discourses on nickel and chromium-plating operations, difficulties, and results obtained in practice.

VATS for nickel plating are of wood, lined with chemically-pure lead, and match-boarded inside. Any well seasoned wood may be used for the outer framework, but a hard wood is advisable. The lead lining must be carefully fitted and all joints made by burning. An inner match-board lining is required to protect the soft lead from injury and accidental short circuits. For this purpose a non-resinous wood, such as spruce or pine is preferable. Resinous woods are apt to exude compounds into the vat which have a detrimental effect on the solution.

If the inner lining swells when in use, and becomes displaced, it may be necessary to fix it firmly in position by wedging in a strong rectangular wooden frame.

Chromium plating vats are almost invariably made of iron. Steel is more rapidly attacked by the solution, the rate increasing with the carbon content of the steel. As, however, the usual practice is to line the vat with hard (antimonial) lead, the actual material of which it is composed is not very important. Glass sheets inside the lining are often provided to prevent the work making contact with the latter, but this is not essential, and is often inadvisable when using the lead-lined vat.

The vats must be provided with ducts along the upper edges, just above the anodes, and connected to an exhauster; the chromic acid spray produced during working, which is very harmful to those operating the solution, is then effectively removed.

Methods of Heating.

Heating of the vat is accepted practice, and may be either by steam, gas or electricity. In the former case, all but the smallest of vats will require fitting with steam coils in the solution. The method is satisfactory, provided an efficient steam supply is available. Electric heating is certainly by far the best method by reason of its efficiency and flexibility. Immersion heaters, preferably oil filled, give good results. They should be thin and of large superficial area, so that a rapid heat transference may take place between the heating element and the solution. Heaters are enclosed in lead cases ; the heating element may be of copper-nickel or some similar resistance wire, wound on insulators on an iron framework placed in the casing, and the whole filled with transformer oil. Such an oil can be used safely up to 100° C. Above this, sludging commences. It is important always to keep the heater full of oil, and to maintain the level of the vat solution above that of the oil in the heater.

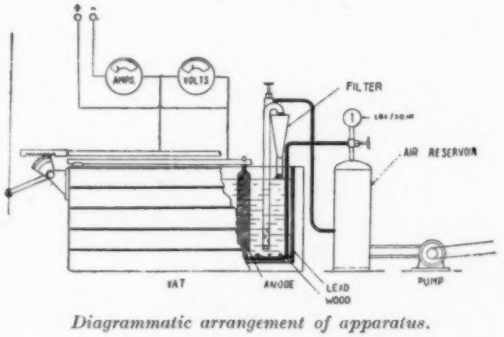
A large vat will require two or more heaters. If two are used, it is a good plan to keep one on continuously overnight, and to use the pair when working the solution during the daytime. About 1 kw. per 100 gals. of solution will provide sufficient heat for still vats. If, however, the solution is agitated by blowing air through, more heat will be required to compensate for the heat loss due to the cold air.

From time to time it is necessary to add oil to the heaters to make up for volatilisation losses, etc. Great care must be exercised when doing this, to ensure that no oil is spilled on the surface of the solution as, should this happen, any article immersed in the vat will be contaminated with oil, and the nickel deposit will be patchy.

It is usual practice to heat chromium-plating solutions by gas, burners being arranged under the bottom of the vat. This tends to make the whole tank rather deep, but a good way of overcoming this drawback is to sink the tank through the floor, so that about two feet stands above floor level in the plating shop, the remainder being in the cellar below. Recently gas heating by flames injected into long tubes arranged in the solution near the bottom of the vat has proved very successful.

Agitating and Filtering.

Nickel solutions are often agitated and filtered continuously. It is not usual, however, to treat chromic acid solutions in this way ; there is considerable disturbance and diffusion from the high current density used, and the gas evolution resulting from the low cathode efficiency.



Diagrammatic arrangement of apparatus.

Solutions may be agitated either by direct circulation of the liquid by a pump external to the vat, or by blowing in air. The latter method has much to recommend it. If the solution is circulated by a pump, this must be made of a material capable of withstanding the chemical action of the vat liquor, and there is always trouble due to leakage, and the danger of contamination of the solution by oil from the bearings.

When agitation is brought about by an air pump, this may be installed in any convenient position, provided it is not too far away from the vat. The most satisfactory pump is a rotary type having only one moving part—*viz.*, the rotor, carried in ball bearings, the machine being kept partly filled with water by connecting two points on the body to the lower end of a cylinder having a capacity of about five or six cubic feet. The bottom of the cylinder is filled with water, forming a seal in the pump ; without the water the latter will not function.

The quantity of air required is more important than the actual pressure. The latter need not be greater than two or three lbs. per square inch, but the quantity will naturally depend on the size of the vat, and the matter should be gone into carefully, as it is not advisable to attempt to alter the air output by variation of the rotor speed (2,000 revs. per min.).

The above type of pump has been found to give excellent results. It requires practically no lubrication, and therefore the risk of oil contamination is greatly minimised. The air supply is also free from dust and grit, foreign matter remaining in the air reservoir.

Quite good results have been obtained with a slow speed blower of the dry type having internal moving vanes fixed on the rotor, and running at 350 revs. per min. As this pump requires lubrication, an oil separator must be installed between its exit and the air reservoir. The chief disadvantage to its use lies in failure to stand up to hard conditions. The wear is considerable, and is due to the abrasive matter which enters with the air. Even with a really efficient air cleaner on the inlet pipe, it is extremely difficult to prevent grit and dirt entering the body. One has only to consider for a moment the atmospheric conditions existing in the vicinity of a plating and polishing shop to appreciate the arduousness of the work put upon a machine of this kind.

The same air supply as that used for agitating can also perform the filtering operation. This is best done by a simple form of air lift pump installed in one corner of the vat, and raising the solution about a foot above vat level, thence allowing it to fall back into the vat after it has first percolated through a suitable filter bag. Felt bags are quite satisfactory, provided they are cleaned regularly. The bag is supported in a cage made of nickel strip. It is advisable to raise the solution well above vat level during filtering as, in this way, the oxygen of the air can the more readily come into contact with it, and so help in the oxidation of impurities and facilitate their removal by the filter.

It is essential that the filter be efficient and able to cope with the solution sufficiently rapidly to keep it free from insoluble matter. If the filtering is not quick enough, the deposits will invariably contain pin-holes due to solid particles suspended in the solution. Particularly when agitation is used must the solution be filtered thoroughly and continuously. Agitation stirs up the anode sludge, and this again will spoil the deposit, unless it is taken care of by the filtering apparatus.

The most satisfactory method of leading the air into the vat is to use two pipes placed on the floor, blocked up at one end and joined together at the other where they merge into a common down lead. The pipes lying on the floor of the vat should be arranged under two cathode rods —*i.e.*, beneath the work, and should have a number of small holes drilled in their upper faces. These holes may be inclined slightly, and should not be greater than $\frac{1}{8}$ in. diameter.

Owing to the action of the compressed air in disturbing the solution, it is sometimes found that the pipes will not remain in place on the bottom of the vat. It is, therefore, necessary to wedge them in place by means of wooden cross-pieces, having notches cut in the under sides to accommodate and retain the pipes in position.

Movement of Cathodes.

Excluding barrel plating, which, for the electro-deposition of chromium has not so far proved to be a commercial success, and will not therefore be discussed in the present article, it may be said that there are two ways in which cathode movement may be brought about: (1) By moving the work continually in one direction through the solution, (2) by using a reciprocating motion. The former is commonly used in repetition work, and necessitates specially designed plant; the articles are usually suspended from a chain which is moving slowly in a horizontal plane.

A reciprocating motion can be given to the work by simple oscillation of the cathode rods, these being supported at one end on rollers, and at the other upon cogs, the rods having racks to engage with these cogs. The cogs being fixed to a common shaft, are given a reciprocating action by a crank and connecting rod working from a small gear-box containing a worm-and-wheel reduction gear. The arrangement can conveniently be built on the end of the vat. The travel of the rods should be adjustable as, with large work, it may not be practicable to have so great a travel as when plating small articles. The maximum movement used by the author was seven inches.

The speed of oscillation is of importance. It must not be too slow, or no benefit will be derived. On the other hand, if too great, trouble may result during plating, because there is a tendency to destroy the cathode polarisation. A speed of 30 complete to-and-fro movements per minute will be found to be all that is required in the majority of cases.

As the cathode rods are only supported at their extremities, they must possess strength sufficient to prevent their sagging when weighted with the cathode articles. Rods composed of a steel centre surrounded by a brass tube give good results. The brass part should be thick enough to give a low electrical conductivity to the bar as a whole, and preclude the possibility of voltage loss.

The anode rods need not be so strong, as they can be given support at points intermediate between their ends. They should be placed in porcelain insulators, and both anode and cathode rods must be securely cross-connected by stout copper bars. The design of the lugs for such jointing of bars, and also for the dynamo cable connections, should be as simple as possible, permitting of rapid removal and replacement. At the same time, it is important that all joints which are to carry current be sound, as otherwise voltage loss and overheating troubles will arise.

So far, little success has resulted from cathode movement in chromium solutions. In any case, the conveyance of the heavy current necessary through moving gear is not easy, and usually necessitates the use of a large number of flexible leads which are rather an encumbrance.

It is sometimes difficult, especially when the cathodes are in motion, to prevent articles falling into the vat. The recovery of such articles from nickel solutions is greatly facilitated if a large net of nickel wire mesh in a nickel frame of the exact size of the vat is arranged to lie just above the pipes on the floor. It is only necessary to raise the frame, when any articles that have fallen in will be brought to the surface.

Anodes.

(a.) *For nickel plating.*—Anodes are chiefly of two types—cast and rolled. The latter are always to be preferred on account of their greater purity and lesser tendency to disintegrate in use. The objection generally raised to the use of rolled anodes is that they will not dissolve readily. This difficulty is easily overcome by the use of reagents in the vat to assist anode corrosion.

Long anodes of small cross-section are better than the older flat type suspended by two hooks. Hooks should, as far as possible, be an integral part of the anode. Perhaps the best method of making the hook is to have a screw cast in the upper end of the anode, and use a strong brass hook tapped to screw on to this. If cast anodes are used, and show a tendency to be dirty, they may be enclosed in bags with the idea of retaining foreign matter set free as they dissolve. The bagging does not cause much inconvenience, and is frequently resorted to.

(b.) *For chromium plating.*—These are almost invariably of lead. As will be mentioned subsequently, it is necessary to employ an insoluble anode in chromium plating, and lead is the best material to use, on account of the readiness with which the trivalent chromium is oxidised at its surface to the hexavalent form. The anodes are made of sheet lead, about five inches wide, and deep enough to reach nearly to the bottom of the vat. They must be removed when the vat is inoperative, and cleaned regularly in order to keep them free from incrustations of lead chromate.

The general layout of a nickel-plating vat is shown in the accompanying sketch; the heaters have been omitted, but are often placed at the ends.

Iron and Steel Institute

The Annual Meeting at Westminster

THE annual meeting of the Iron and Steel Institute, held at the Institution of Civil Engineers on May 5-6, was full of interest. Following the business meeting and the election of new members, the president, Colonel Sir Charles Wright, presented the Bessemer Gold Medal to Professor Henry Louis, of Newcastle-on-Tyne, on whom the choice had fallen for this distinguished award. In making the presentation Sir Charles said that to Professor Louis belonged the credit of being the first to introduce elementary metallurgy and metallography as a part of the curriculum of naval architecture and engineering.

Technical papers covering a wide range of subjects were submitted at this meeting which can only be briefly summarised here. In addition to papers the Fourth Report on the Heterogeneity of Steel Ingots, by a Joint Committe of the Institute and the National Federation of Iron and Steel Manufacturers, was also presented for discussion, a reference to which is made elsewhere in this issue.

Recent Developments in the Greenawalt Sintering Machines

The application of sintering processes for agglomerating fine ores as well as fine dust has resulted in the satisfactory use of ores that were formerly difficult and unprofitable. Many types of machines have been developed for this purpose, and Mr. J. Tornblad discussed recent improvements in the Greenawalt system, which was introduced in Britain in 1920. This sintering system is intermittent in operation. The material to be sintered is placed in a pan-shaped furnace and subjected to a down-draught blast of air drawn through grids in the bottom. The upper surface of the charge is fired, and the sintering action proceeds through the charge from the top downwards. After sintering, the charge is removed from the pan and the operation repeated.

As a result of experience in the application of this process, it has been found that the mixing and handling of the raw materials and the subsequent charging of the pans with the mixture to be sintered are not altogether satisfactory, resulting in slow sintering of the charge and a rather large proportion of unsintered or partly sintered material, the so-called "return fines." It is shown that unsuitable arrangements are provided for taking care of and separating the fine particles of ore and dust, which are unavoidably sucked through the grate by the exhaust fans, as well as clouds of dust that arise when the pans are tipped.

In view of these and other disadvantages, a number of changes and improvements have been made in the design and arrangements of this sintering apparatus. These developments are discussed very fully by Mr. Tornblad, and practical results show that they have reduced stoppages, wear and tear, and repairs very considerably. In addition, the increased capacity, calculated per unit grate area of the sintering pans, has also decreased the sintering cost. As evidence of the efficient operation of the latest Greenawalt sintering apparatus and appliances, he cites a plant at the Prague Iron Industries Co.'s works at Kladno, Czechoslovakia, which has been in continuous operation since December, 1930. This plant is equipped with three sintering units, each pan having a grate area of 100 sq. ft., with a total daily production of 450 to 500 tons of sinter from the following ore and fuel mixture :—

30% calcined spathic ore (chamosite) fines.
25% pyrites residues.
15% Swedish magnetic concentrates.
15% roll scale.
10% blast-furnace flue dust.
5% coke breeze.

The actual sintering costs for the plant amount to 12·67 Czech crowns, or 1s. 7d. per ton of finished sinter, from which all the fines below five-sixteenths inch in size have been screened off.

Since the commencement of continuous operation (December, 1930) no repairs or replacements have been necessary, with the exception of a few grate bars in the pans which proved to be faulty castings. One of the exhaust fans was opened up for inspection after a year's run, when it was found that neither the fan-wheel nor the diffuser were any the worse for wear. The fans will therefore be good for several years' continuous operation.

The Theory and Practice of Nitrogen Case-hardening.

In a paper dealing with the nitrogen case-hardening process Dr. Adolph Fry briefly summarised the object of adopting some process which could be employed to produce a hardened surface on steels at lower temperatures than were then necessary. Nitrogen offered possibilities, and the nitriding process then developed produced an extremely hard case by simply heating parts made of special alloy steel in ammonia gas at about 500° C. and allowing them to cool down slowly, subsequent quenching being dispensed with. The theoretical explanation of the phenomena involved at first offered considerable difficulty, but with the growing importance of nitrogen hardening various workers engaged actively in theoretical investigations, and their researches provided a clearer conception of the theory of the process.

Dr. Fry referred briefly to the phenomena occurring during the nitriding process in the binary iron-nitrogen system. The action of nitrogen on pure iron at low temperatures causes increased hardness; the increase, however, is not so marked as to be of importance technically, but if the iron is alloyed in suitable proportions with other elements, such as chromium, aluminium, titanium, molybdenum, the action of active nitrogen on the steel heated to a suitable low temperature will impart an extraordinarily high surface hardness which far exceeds the degree of hardness obtainable by quenching carbon steel. The high degree of hardness obtained is caused by slip interference due to the nitrides that are formed in large quantities by the reaction of the active nitrogen with the alloying elements in the steel.

The maximum hardening effects in nitriding would be obtained if the whole of the nitrogen absorbed was combined with the alloying elements, without leaving an excess of nitrogen. In practice, however, there is usually an excess of nitrogen. This accounts for the fact that for alloy steels, as for plain carbon steels, the eutectoid temperature of 590° C. retains its importance in the nitriding process, though this temperature limit may be more or less affected by the addition of alloying elements.

The nitriding process differs fundamentally from the carburisation process of case-hardening. In the latter the carbon is soluble and capable of penetration from the outer to the inner layers. In nitriding, however, as the process progresses the absorbed atoms of active nitrogen are forced to penetrate an already saturated layer of continuously increasing thickness. Attempts have been made to accelerate the penetration of nitrogen into alloy steels, and some methods have been successful, but only to a very limited extent.

The author gave analyses of several types of nitriding steels, and their tensile properties after suitable heat-treatment. First in importance are those alloyed with chromium and aluminium. It is of interest to note that a small addition of molybdenum to these steels gives a

marked improvement in the facility of heat-treating large sections in the machinability and in the toughness of the nitrided case. Reference was made to precipitation-hardening nitriding steels recently developed to provide a comparatively soft steel that is easily machined prior to nitriding, and yet capable of producing a hard core. The analysis of one of these steels is as follows :—

C.	Si.	Mn.	Ni.	Al.	Ti.
0·1 ..	2·55 ..	1·4 ..	2·2 ..	0·5 ..	3·9

In the hardness-depth curve of this steel before and after nitriding, which is given in the paper, it is shown that the hardness of the core is considerably increased, due to precipitation hardening. Only recently developed, this process should prove to be of value where nitrided parts are required to withstand high surface pressures.

In conclusion, the author mentioned the extension of nitrogen case-hardening to suitably alloyed cast iron which had given interesting results, particularly in the case of cylinder liners for internal combustion engines. The best results, he said, were obtained with centrifugally-cast parts, a method first successfully applied on an industrial scale by Hurst.*

Nitrogen-hardening of Cast Iron.

Some experimental results were described in a paper by Mr. J. E. Hurst. These form part of an investigation of the degree of hardness obtainable, and the general strength properties of aluminium-chromium cast iron suitable for nitrogen case-hardening. The composition of the alloy cast iron is within the requirements of the commercial product known as Nitricastiron.

The testing procedure adopted was mainly in accordance with that laid down in the British Standard Specifications for piston-ring material, and tests were made on centrifugally cast and sand-cast specimens in the as-cast, annealed, heat-treated, and nitrogen-hardened conditions. In the as-cast condition, this alloy cast iron shows excellent strength properties, the modulus of elasticity (E N value) and Brinell hardness values being higher, and the permanent set values lower than those usual for ordinary cast iron made to the requirements of the British Standard Specifications referred to. The centrifugally-cast material possesses a higher strength value, E N value, and Brinell hardness, and a lower permanent set value than the same material in the sand-cast condition. In both the centrifugally-cast and sand-cast samples annealing was accompanied by a lowering of the Brinell hardness, an increase in the strength and permanent set values, and practically no change in the E N value.

This alloy cast iron is susceptible to heat-treatment by hardening and stabilising, and with the treatment adopted the strength level and hardness attained in annealing were maintained. Its treatment with ammonia gas, under the conditions of the commercial nitrogen-hardening process, is accompanied by surface hardening, and a diamond hardness value of 982, with a penetration of 0·018 in., was obtained on the centrifugally-cast—greater than in the sand-cast test-pieces, and lower than in the control specimens of Nitralloy steel. The microstructures of the alloy material in each condition have been examined, and the coherence and freedom from spalling of the nitrogen-hardened surfaces demonstrated.

The Pearlite-Austenite Inversion.

This paper, by Professor Sir H. C. H. Carpenter and Dr. J. M. Robertson, deals in the first place with the constitutional aspects of the formation of pearlite. The iron-carbon diagram shows that in the absence of other elements this change takes place at a constant temperature, but this applies only to equilibrium conditions. Under ordinary conditions of cooling the change is spread over a range of temperature, but if cooling is stopped within this range the change proceeds to completion. The addition of other elements also causes the change to be spread over a range of temperature, but in this case it does not complete itself if cooling is stopped within the range.

The structural features of the formation of pearlite were then discussed. One view of this is that the ferrite-cementite lamellæ are formed along the crystallographic planes in the austenite. In general, however, each austenite grain gives rise to a number of sets of lamellæ, which are not straight, and which do not meet at angles that suggest any relation to the crystallographic planes. Consequently, the authors have concluded that the directions of the lamellæ are controlled by other factors.

Three ways in which the alternate plates of ferrite and cementite could be produced from austenite were discussed. First, the change might begin with the formation at intervals throughout the austenite of thin plates either of ferrite or of cementite, followed by the production between these of similar plates of the other constituent. It might then proceed by the increase in their thickness, ferrite and cementite being deposited alternately, while the composition of the austenite oscillated between two values, one slightly to the right, the other slightly to the left, of the eutectoid. Secondly, the change might proceed by the precipitation of alternate layers of ferrite and cementite, so that the formation of pearlite would begin at a point and spread through the austenite, the direction of growth being at right angles to that of the plates. Thirdly, the ferrite and cementite might form simultaneously, and a growing particle of pearlite would consist of a group of plates advancing edgewise into the austenite. Careful study of a number of specimens showing pearlite in the course of formation indicated that the change takes place mainly, if not entirely, in the way last described. Numerous micrographs show this.

The effects of varying the carbon content and the rate of cooling on the form of the pearlite were investigated. It was observed that with slow cooling and low carbon content the pearlite areas did not exhibit any tendency to assume any particular shape. As the rate of cooling and the carbon content were increased, however, the areas tended to grow radially, and perfect radial growth was obtained when pearlite began to form in the absence of pro-eutectoid ferrite. This radial shape is attributed (1) to the tendency for growth to take place, so that the edge of the plates will always be presented to the direction of growth, and (2) to the fact that in this way the maximum amount of austenite is transformed in a given time.

As the rate of cooling is increased, ferrite crystals tend to assume elongated shapes, while pearlite crystals tend to become spherical. Because the conditions attending the formation of these constituents are different, their response to variations in the rate of cooling is different. When ferrite is forming, excess carbon is transferred to the austenite, whereas when pearlite is forming there is no change in the composition of the austenite.

The constitutional aspects of the transformation of pearlite to austenite were then discussed, and it was shown that under ordinary conditions of heating the observed Ac_1 point occurs at a higher temperature than the equilibrium eutectoid point. Consequently, when specimens are heated at the temperature of the observed Ac_1, they are in a region where austenite containing either more or less than the eutectoid proportion of carbon may be formed. As cementite dissolves more slowly than ferrite, the formation of austenite containing isolated globules of cementite is a stage in the change under these conditions. The formation of austenite begins at points on the ferrite-pearlite boundaries, and from them irregular areas spread. Their shape bears no relation to the structure of the pearlite from which they are produced.

Nitrogen Needles in Steel and Arc Welds.

An investigation has been carried out by Mr. L. W. S. Schuster, mainly to ascertain the alteration of the structure of hypo-eutectoid steel containing nitrogen, caused when the more common constituents were added in quantity. The information was required particularly for arc welds.

* Director of the Sheepbridge Stokes Centrifugal Castings Co., Chesterfield.

so that from microscopic examination alone it might be possible to determine, within limits, the extent to which a weld had been contaminated by the atmosphere. Since the investigation includes steels just as much as welds, the conclusions, which are given by the author in a paper, may equally be applied to structures obtained in the hypo-eutectoid zone of the more common steels after various nitrogen-hardening treatments. The original intention of the author was to ascertain the effect of nitrogen on silicon and manganese steels. Later it was found necessary to explore the influence of carbon, and although it was not possible to give the same close study of the influence of nickel and chromium, to which the investigation was extended, the results will prove valuable as a basis for future investigations.

In a general survey of iron, without added elements, the author's investigations supported the view of Bramley and Turner that when the nitrogen content of Armco iron reaches 0·22% the structure consists entirely of braunite in ferrite and no needles are present. In regard to the nitrogenisation of carbon steel, given a sufficiently slow rate of cooling, carbon can be added in quantity without the inhibition of the needles. Supplementary experiments show that if sulphur and phosphorus in commercial quantities have any capacity for preventing the formation of needles, it can only be slight. Results obtained from welds made with manganese steels show that with manganese added to ordinary bare-wire electrodes, there is a tendency for the nitrogen content to decrease until it reaches a figure of 0·080%. The experiments recorded show that 1·45% of manganese, even after a comparatively slow rate of cooling, inhibits needles in welds having a carbon content of well under 0·12%. They also tend to show that the lower figure of 1·16% manganese is more than sufficient with welds containing 0·083% of carbon. They show definitely that 0·81% of manganese is insufficient.

Silicon enables ferrite to hold a greater amount of nitrogen in solution, and the addition of this element almost invariably prevented the formation of needles. With metal containing about 0·25% of manganese and from nil up to 0·12% of carbon or over, the border line where needles are inhibited occurs when the silicon content is round about 1·1%. With silicon steels the rate of cooling, as long as it is not unduly quick, does not appear to affect the result—that is, provided that the manganese and carbon contents are low. Naturally, with the manganese content raised, the silicon content for inhibition is reduced.

Nickel seems to inhibit needles in a similar manner to manganese. With different rates of cooling, when nickel is present the manganese and carbon contents necessary for needles to be entirely replaced by braunite is lower than when nickel is absent. With bare-wire welds containing nickel, needles may be absent owing to a high nitrogen content and the replacement of needles by braunite. With steel containing, say, 0·50% of manganese, and up to 0·18% of silicon, the border line apparently occurs when the nickel content lies at about 2·5%. With 0·25% manganese and negligible silicon content, the nickel content lies close to 2·5%.

In regard to chromium, the author indicates that this element exerts a less powerful influence in inhibiting needles than manganese.

The Lattice Spacings of Iron-Aluminium Alloys.

The investigation of lattice spacings described in a paper by Messrs. A. J. Bradley and A. H. Hay shows that the FeAl alloys in the range 0 to 32·6% aluminium by weight behave in an extremely complicated manner. The results were compared with those previously obtained for the structure changes. Both annealed and quenched alloys with from 0 to 10% of aluminium have a random atomic distribution, and show a linear increase in lattice spacing. Annealed alloys with from 10 to 17% of aluminium have a constant value for the lattice spacing. The Fe_3Al type of structure exists in this region, emerging gradually from the random arrangement. The lattice spacing of annealed alloys drops slightly from 17 to 20% aluminium, and the structure gradually changes to the FeAl type.

Quenched alloys differ from annealed alloys beyond 10% aluminium. The lattice spacing increases right up to 14% aluminium but more slowly than before, the distribution remaining random. There is a sudden fall in lattice spacing at 14%, which corresponds to a change from the random state to the FeAl type of structure. The lattice spacing oscillates slightly in value from 14 to 20%. Both annealed and quenched alloys have the FeAl type of structure from 20% aluminium onwards, but the lattice spacings differ according to the previous heat-treatment. Alloys quenched from 700° C. obey the linear law. Alloys quenched from 600° C. and annealed alloys show a less uniform increase in spacing.

The authors suggest that some of the peculiarities in the lattice spacings between 10 and 20% aluminium may be due to a change in the valency of the iron atoms ; these are probably null-valent between FeAl and the approximate composition Fe_2Al, but with less aluminium the valency of the iron atoms is likely to increase.

The Heterogeneity of a Sand-cast Steel Ingot.

In order to study the heterogeneity of large alloy steel ingots made in the steel plant of the Skoda Works, Pilsen, some ingots—which were cast and became solid under various conditions—were investigated. In some cases these conditions deviated from the usual practice. An extreme instance was an ingot cast in a preheated sand mould, so that the rate of solidification was considerably slower than that in a chill-cast ingot. In an investigation of these ingots, the results of which were given in a paper by Dr. A. Kriz, the usual methods were employed to determine the distribution of sulphur segregations, the macro-structure, and the chemical composition in different parts of the ingot. The work was primarily concerned with the sand-cast ingot, but a comparison was made with the results of the investigation of large chill-cast ingots of approximately the same chemical composition.

The shape of the sand-cast ingot, production data, and casting procedure were given in detail. A sectional illustration of the ingot on its longitudinal axis shows that the total depth of the pipe was 60% of the total height of the ingot, while its diameter at the centre amounted to 13% of the diameter of the ingot. The surface of the axial section was machined and ground, and subsequently etched and examined. The chill layer of the ingot was very thin, and did not contain so many blowholes as a chill-cast ingot. The columnar crystals did not originate immediately from the chill layer. In the granular zone it was shown that the differences in the sizes of individual crystals were smaller than those of chill-cast ingots. A bar cast from the upper part of the ingot showed on metallographic examination that the ferric network was very fine. Deeper inside the ingot the ferritic boundaries of the primary granules were clearly visible. The secondary structure consisted of small grains of pearlite enclosed in ferrite. Large eutectoid areas of pearlite and islands of sorbo-pearlite did not occur.

The sulphur segregations, owing to the slower rate of cooling of the ingot during solidification, differed considerably from those in a chill-cast ingot. The vertical segregations were much broader and more pronounced. Drillings were analysed, and the results of twenty-six samples were given. The properties of this sand-cast ingot were compared with those of chill-cast ingots, which had approximately the same chemical composition.

Behaviour of Manganese in the Acid Open-hearth Process.

The absolute percentages of the particular constituents in the steel bath or in the slag depend upon the proportions

of the steel bath and slag, as well as upon the relative concentration ratios. It was on these lines that Messrs. E. Maurer and W. Bischof dealt with the basic open-hearth process in a paper entitled, " On the Reduction of Manganese in Steel Making."[1] In the present paper the authors deal in the same way with the manganese reaction—

$$FeO + Mn = MnO + Fe$$

as applied to the acid open-hearth process. Then groups of samples were taken from actual works melts containing varying percentages of slag and from 5 to 11% of lime. The K value of these samples as given in the equation—

$$K = \frac{(FeO).Mn}{(MnO)} = \frac{(Fe).Mn}{(Mn)}$$

is plotted against the percentage of silica, and the curves show that the K values drop slightly with increasing percentage of lime, the percentage of silica in the slag remaining the same. A further large number of samples containing higher carbon silicon and manganese contents, were investigated to ascertain the effect of these constituents on the equilibria of the manganese reaction, and K values plotted in terms of the iron concentrations and manganese concentrations of the slags. The application of K values to the actual metallurgical process at the steelworks was discussed, and steelworks data given. Proceeding from these data, the authors establish the equilibrium constants of the equation—

$$K = \frac{(Fe).Mn}{(Mn)}$$

by the contraction process, for approximately 1,600° C. Using these K values and the percentages of charge manganese, percentages of slag, and the loss figures as arrived at from works data, they work out the manganese concentrations of the metal bath and the Fe and Mn concentrations of the slag. They are able to show that the figures so calculated are in very good numerical agreement with those found in practice. This is the first time that the laws of physical chemistry have been applied, mathematically, to the practical steel-melting process.

The Action of Sea Water on Mild Steel.

This research consists of laboratory tests of mild steel in conditions of total immersion in stagnant natural sea-water and N/2 sodium chloride at a constant temperature of 25° C. and under 760 mm. pressure. In previous investigations on the subject no mention has been made of the evolution of hydrogen gas during the corrosion in salt-water, natural or artificial. Dr. G. D. Bengough and Dr. A. R. Lee were led to investigate the matter by the discovery that hydrogen was slowly evolved when mild steel was corroded in N/2 potassium chloride or N/2 sodium chloride, either in oxygen or in air. Consequently, experiments were made in which mild steel, in the form of horizontal discs, was totally immersed in natural sea-water, and a variety of salt solutions beneath atmospheres of air or oxygen for periods up to 150 days. The results show that a large proportion, often one-half, of the corrosion in sea-water was due to the evolution of hydrogen gas. In the absence of oxygen no hydrogen evolution could be observed at the end of 110 days. With the rate of oxygen supply used in this research, the rate of corrosion in sea-water beneath an air or oxygen atmosphere was usually found to be faster than that in N/2 NaCl solution, due mainly to the increased amount of hydrogen evolution. The rate of corrosion in sea-water in the presence of oxygen was only about 20% faster than that in air ; in N/2 NaCl the rate is increased by two and a half times.

Oxygen-absorption/time curves in sea-water beneath an oxygen atmosphere were found to fluctuate about the mean position of the N/2 NaCl curve. These fluctuations were associated with the presence of magnesium and calcium salts. It has not yet been found possible to prepare a mixture of inorganic salts, with or without saponin, which would give the high rates of hydrogen evolution found with sea-water. These high rates are probably associated with the presence of organic matter in solution. Partial removal of the organic material in sea-water by means of animal charcoal or centrifuging had relatively little effect on the corrosive behaviour of the sea-water, but treatment with boiling potassium permanganate caused its behaviour to approximate to that of a solution of mixed chlorides of sodium, magnesium, and calcium similar in concentration to sea-water.

The authors suggest that the evolution of hydrogen gas may be an important factor in determining the adhesion of paints on steel immersed in salt-water.

(1) E. Maurer and W. Bischof : *Zeitschrift für physikalische Chemie*, 1931, A. vol. 157, pp. 285–309.

The Determination of the Porosity of Tin Coatings on Steel.

It has long been appreciated that the thin tin coating on tinplate is seldom perfectly continuous, minute holes invariably being present that cannot be seen by visual examination. The presence of these pinholes or pores is revealed when the tinplate is subjected to micro-examination or is exposed to a corrosive medium which does not perceptibly attack the tin during the time of exposure, but attacks the steel with the production of a visible corrosion product. An accurate and convenient method of determining the porosity of tinplate is thus of importance, and an investigation with this object in view has been carried out for the British Non-Ferrous Metals Research Association as part of extensive work to improve the quality of tinplate. The investigation has been carried out by Messrs. D. J. MacNaughton, S. G. Clarke, and J. C. Prytherch, the results of which are given in a paper.

The authors have found that when tin-coated steel is kept for some time in hot water of high purity, spots of iron rust appear over its surface ; these spots are sharply localised and strongly adherent. Certain conditions are given as essential to secure the maximum number of spots. These spots the authors consider a satisfactory index of the porosity of the coating.

The results of ferricyanide tests have been compared with those obtained with the hot-water test. The results of a number of tests are given, and in all cases the hot-water test has proved satisfactory. In the preliminary tests it has been shown that pores in other cathodic coatings on steel—such as nickel, chromium, and copper—are also revealed on immersion of the coated metal in hot distilled water, the development of the rust spots taking place more rapidly than in the case of tin coatings on steel.

The Properties of some Silico-Manganese Steels.

The effect of silicon and of manganese on the mechanical properties of steels containing 0·36 to 0·54% of carbon has been investigated, and the results given in a paper by G. Burns. In normalised steels suitable for structural purposes it is shown that both silicon and manganese raise the elastic limit, yield-point, and maximum load, and lower the elongation and impact figure. In the presence of upwards of 1% of manganese, silicon in excess of 1% is specially detrimental to the ductility and impact value. Silicon has a slight effect in raising the yield ratio, but the properties of the steels are largely accounted for by the carbon and manganese contents.

In the oil-hardened and tempered condition, both manganese and silicon raise the tensile strength and 'ower the ductility and impact value of the steel. Manganese has a greater effect than silicon, and also causes a greater increase in the value of the yield ratio. In general, silico-manganese steels require a high hardening temperature to develop their best mechanical properties, though there are indications that as the silicon content increases, the actual benefit derived from the high hardening temperature becomes less. Silicon steels containing less than 1·5% of manganese are susceptible to mass effect, and if a high

(*Continued on page* 28.)

The Advance of Electric-Arc Welding

By Edward Dacre Lacy

In these days the most modern processes, which promise increased efficiency, must receive full and careful consideration, and be pressed into service. In this article the author indicates to what extent this is being done at a large shipbuilding works in regard to welding processes.

THE shipbuilding industry offers considerable scope for the use of electric-arc welding and as soon as conditions in this industry improve considerable progress will become manifest. Welding processes have already been found suitable for the building of smaller vessels, and with further development and increased experience in operations their extension to vessels of larger size is only a question of time. The high relative strength of welded joints coupled with their convenience in use, are important factors which are increasing the application of welding processes, not only for structural purposes but also for the construction of boiler deck and below-deck machinery.

In the actual construction of merchant vessels electric-arc welding has many different uses; thus for instance, in building up corner and angle bars the process is cheaper and quite as effective as forging them. Bolts can be welded on steel plating for deck-plank fastenings thus avoiding the necessity of piercing the decks and possible damage to fitting below, where fitting-out work is well advanced.

Further, in this connection, where water-tight compartments have already been water-tested, welding can be used instead of drilling, riveting, and caulking, and the cost of a re-test of the compartment saved. Welding can also be used in the manufacture of oil and water tanks for use on board ship. In building up pipe connections for pumping and draining systems electric welding is of great assistance. Pipes with flanges loosely attached can be put into position temporarily, the flanges and pipes set to correct position and levels, just caught by electric welding, and then removed and the welding completed. In many cases electric welding can be used in awkward corners where there is not sufficient space to rivet.

Ventilation trunks and deck coamings can be rolled up, or bent to shape, and welded more cheaply than by the use of rivets. In repair work electric welding has been used extensively for some years, and, in addition to those cases which have been described above applying to ship-building, welding can be employed very largely in alteration work, to avoid the necessity of lifting large pieces of machinery to get in new fastenings, and for restoring corrugations of foot-plates and ladders by means of specially hard electrodes, thereby saving the expense of new foot-plates and ladder treads. Again, electric welding can be used for reinforcing deck pipes and hawser pipes when worn thin with the rub of cables. In the repair of small castings, and more particularly steel castings, and in connection with the inner bottom plating when it has been worn thin welding can also be used.

One of the largest of the shipbuilding firms making wide use of electric-arc welding and oxy-acetylene welding is Vickers-Armstrongs, Ltd. The wide range of products of this Company provide considerable applications for welding in connection with other products in addition to those connected with shipbuilding; thus, for instance, they make machines for the complete manufacture of Portland cement. These are of a construction analogous to boilers, and consist primarily of a rotary kiln which is designed to rotate approximately one revolution per minute. Built of heavy boiler quality steel plates, with machined joints, these kilns are lined with firebricks. A large amount of welding is now embodied in both the main cement machinery and the auxiliary parts, such as hoppers, chutes, piping, kiln and mill hoods, and general minor constructional work.

In the construction of all types of industrial machinery the application of welding is making steady progress. All sizes of condensers, suitable for both marine and land practice, are being constructed extensively with the aid of welding; the process is also being applied to the construction of evaporaters, heaters, de-aeraters, and other boiler-house auxiliaries, such as are used for modern feed-heating systems.

An all-welded condenser for a large turbine by Vickers-Armstrongs is illustrated in Fig. 1. This condenser weighs about 28 tons, its dimensions being approximately 20 ft. × 19 ft. × 17 ft. A large number of twin-shell condensers have also been constructed, where the design of turbine has necessitated this type. Multiple-effect evaporators of the largest size in this country, and probably in the world, have been constructed by the same Company, and also de-aerators up to 40-ft. high, in all of which welding played an important part in the construction.

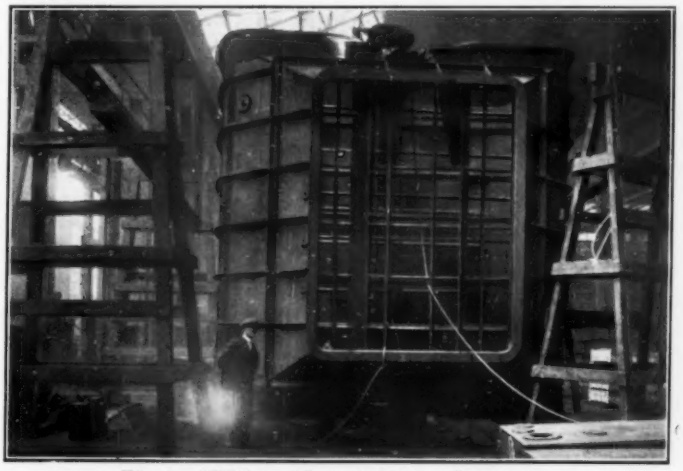


Fig. 1.—Welding of large turbine condenser.

While the method of construction of the condenser is of interest it is as important that the proportions of the condenser should be selected so as to give very efficient results, and the same remarks apply to any feed-heating system, where efficient and economical working can only be obtained by a careful analysis of the operating conditions before the proportions of the plant are settled; Vickers-Armstrongs, besides having advanced manufacture to the latest practice, have also obtained a knowledge of operating conditions which enables them to select the most desirable combinations of components which will give, not only first-class plant manufacture, but also a highly satisfactory plant in operation, which incorporates on both sides all the latest improvements of modern design.

Amongst other products manufactured by welding in the Barrow Works of Vickers-Armstrongs are condenser

Fig. 2.—Welding of flange on casing of large gyroscope.

Fig. 3.—The cone end of casing of gyroscope.

flanges and gear-cases, a number of which have recently been shipped to South Africa. An interesting welding job is shown in Figs. 2 and 3, which illustrate parts of a large gyroscope. In Fig. 2 the flange is shown in the process of being welded to the casing. This flange is made in two pieces and welded together. Fig. 3 shows the cone end of the casing. It is made in halves and welded together. The flange of the large end is welded in place, while the casting on the small end is riveted and welded. Other applications in these works include:—Water evaporators (a recent example being the production of 16, each dealing with 3500 tons of water per 24 hours, welded entirely without riveting), condenser shells, water tanks, fabricated structures (including large L.P. steam pipes), pad seatings in ships for machinery valve fittings, pipe flanges and ship-stanchion flanges, large stud fixings for ship's deck plating, coamings around ship's hatches, engine-room skylights on ships, and light bulkheads to main structure.

Bearing Metals of To-day

In the study of bearing metals, as reported by C. H. Bierbaum, in a conference on metals and alloys in Cleveland recently, the first significant fact is that in not a single case has a pure homogeneous metal given satisfactory service. All bearing metals are alloys made up of two or more phases, and these should consist of hard and relatively soft microscopical particles intimately mixed. Micro-examination of the run-in surface of long-life bearings showed that the seemingly high burnish really consisted of the hard crystals in relief, and the alpha crystals at a level about 6 microns lower. These slight depressions hold the lubricant, possibly in a completely solid form whilst the pressure is on, and this prevents the scoring when surfaces come into contact. What constitutes a bearing metal can still be defined as an alloy capable of retaining a lubricant on a bearing surface. Illustrations were taken from the copper-tin series in which enough tin is present to form a delta constituent, and from other copper alloys—*e.g.*, brass which does not form different micro-constituents, and even the manganese bronze with different compositions which does not give hetrogeneous micro-structures, are not bearing alloys. The same is true of aluminium bronze, where the difference between the two crystals is very slight. The bad effect of heat-treatment was instanced in regard to an English railway's experience in getting over breakages in locomotive bronze castings by quenching, but the wear resistance was much reduced. In good practice, the journal and bearing should polish one another, so that the hardest constituent in the bearing alloys should not be abrasive to the journal, which ought to be homogeneous, whereas the bearing should be in a high degree hetrogeneous. When this is not so, then disaster follows, as in the case of cast-iron rolls in an aluminium bearing, which got red hot within an hour's run. The micro-examination showed that the aggregate area of hard crystals bearing upon one another was only 1·8% of the total bearing surface, and although the softe crystals had supported a share of the load, the harder crystals had interlocked and caused the failure of the bearing.

The necessity of having the proper microstructure quite apart from the correct composition was shown to hold good with the tin base bearing metals, and an interesting series of casting experiments with babbitts showed that i the metal was chilled too severely, then the hard copper epsilon crystals which separate with normal rates of cooling were suppressed, and a shorter life bearing resulted from the chilling. In this case a sufficiently hard journal was needed to save scoring, as had been found in aeroplane service. Comment was passed on the varying results obtained by means of destructive and short-time testing of bearing metals, which were stigmatised as possessing no value compared with service tests, which, although prolonged gave results which were conclusive, chiefly from the examination of the structures and that of the journals running in them. A recent improvement in bearing metals was commended as a nickel phosphor bronze, in which 1% of nickel, whilst not hardening the alpha crystals, causes the delta constituent to lose its eutectoid structure and become a homogeneous solid mass, with great abrasion resistance. Two other new developments recorded were the us of nitrided nitralloy steel, with its high degree of homo-geniety as compared with case-hardened skins, and also chromium-plated surfaces, which are hard and free from cracking. As a final protest against damage to bearings, the improper tooling was referred to as most harmful when it disturbed the natural crystal arrangement and left disturbed areas to be worn off before a run-in skin could be formed. The finishing cut should be with the sharpest tool, and at high speed, as instanced by the use of diamond cutters, even for babbitt, which gave extra long life to connecting rod bushes undergoing severe service.

SAND SPUN PIPES

With Special Reference to a Development at the Works of the Staveley Company.

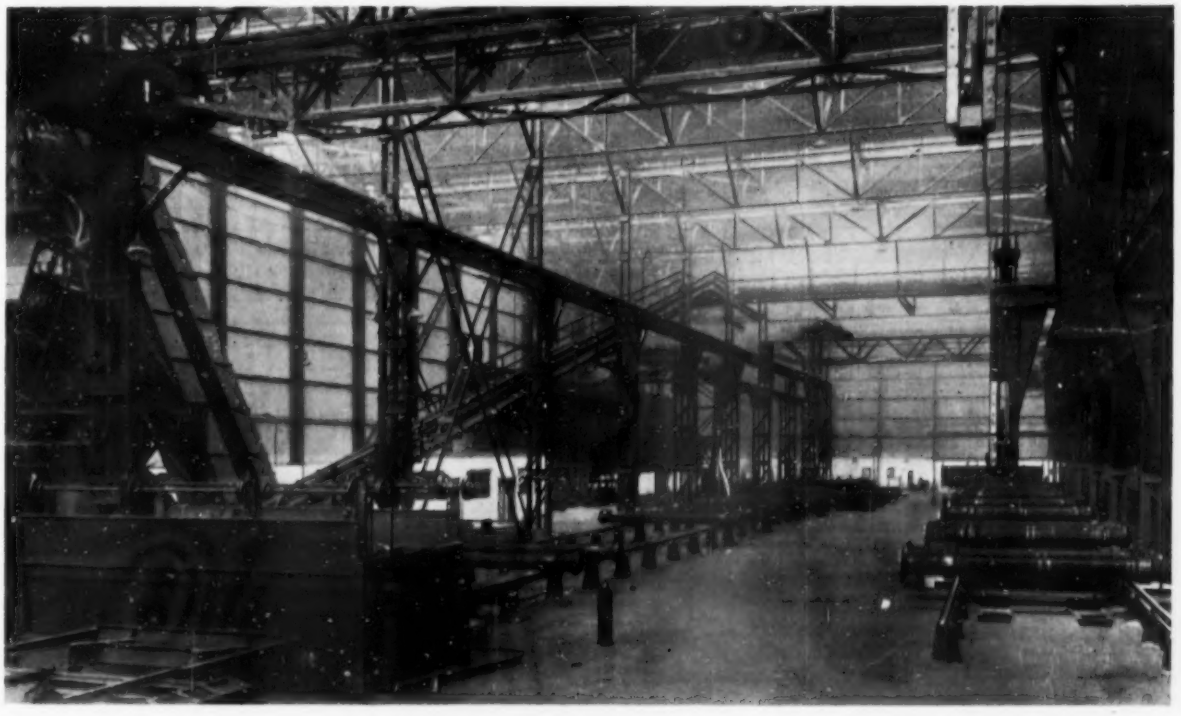
By J. B. Allan.

Iron ore has been smelted by the Staveley Company and its direct lineal ancestors, within the boundaries of its present works, for the last 250 years, while its books of accounts form a continuous record from 1682 to the present time. For about the last 100 years cast-iron pipes have formed the main outlet for the iron so made, and until last year the vertically-cast pipe, cast in pits, predominated at these works, but pipes are now cast centrifugally in sand moulds, and the plant and process are described in this article.

THE earlier practicable methods of centrifugal casting all made use of metal moulds, water-cooled or otherwise, and it was not until the development in America of centrifugal casting in sand moulds that the Staveley Company felt satisfied that the correct method of centrifugally casting pipes had been attained. Hence, in 1929, it was determined to put down a plant for the manufacture of cast-iron pipes of sizes from 4 in. to 12 in. inclusive in sand moulds by a centrifugal process, under licence from the Sand Spun Corporation of America. Work was commenced in the early part of 1930, and the first pipe was cast on June 3, 1931. One-shift working immediately followed, and in the following October two-shift working, a condition which has been maintained from that time.

The plant is housed in a steel-framed building 420 ft. long by 150 ft. wide and 63 ft. high to the eaves. This building is divided into three main bays, while in addition there is a lean-to running the full length of the building on the south side, together with three secondary buildings running at right-angles to this, each of which contains a proving and dipping unit. On the north side of the main building an open overhead crane gantry covers the raw material stockyard.

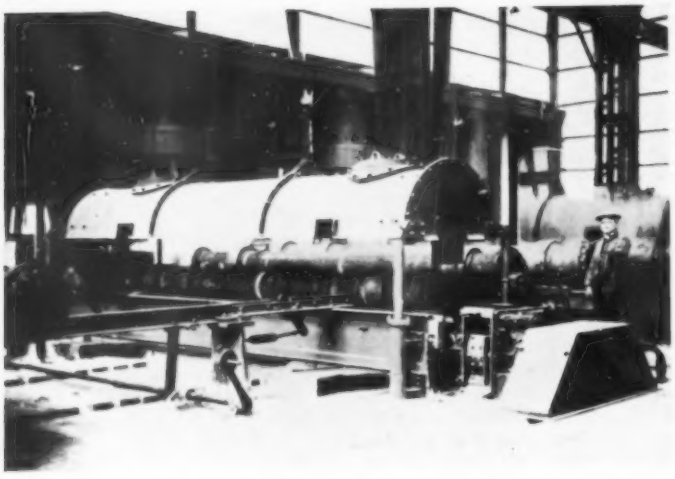
Melting Plant.—The melting plant consists of three cupolas of 4 ft. 6 in. diameter, designed and constructed by the company's own staff. Each is of 15 tons per hour capacity, and is provided with two rows of tuyeres, five in each row. Each tuyere is provided with a damper, so that effective distribution of the blast may be obtained. These cupolas are of the drop-bottom type, and were designed for uninterrupted working periods of 24 hours each. This they have proved well able to do. Blast air is supplied by one of two electrically-driven centrifugal fans, each capable of delivering 6,000 cub. ft. per min., against a head equivalent to 36 in. W.G. when running at 1,700 r.p.m.



General View of Main Shop.

Moulding Flasks.—The flasks for containing the sand moulds are cast-iron cylinders drilled to ensure satisfactory venting, and fitted with two steel tyres upon which they run during the spinning operation. At that end of the flask in which the mould for the socket-end of the pipe is to be made, there is a machined detachable ring, the object of which is to fit the socket pattern, thereby ensuring concentricity at this end between the pattern and the flask. At the opposite, or spigot-end, a flange is secured to the flask. The periphery of this flange is machined, and a casting which serves a dual purpose of a sand-hopper and a centring device ensures concentricity at this end between the flask and the pattern.

After the mould has been made, a cover plate is bolted to the flange, previously mentioned. This plate, called



One of the Spinning Machines with the Hood raised for changing Flasks.

the spigot-end plate, contains a groove on its inner surface into which sand is rammed, thus forming sand inset against which the metal of the pipe abuts. A hole in the middle of the plate forms the entrance through which the molten metal is poured. It will therefore be seen that the molten metal comes in contact with sand only, nor does any form of chilling enter into the process. Hence the pipe is a sand casting, just as the pit-cast pipe is a sand casting. Those qualities, such as lack of brittleness, ease of cutting, etc., qualities largely conferred by reason of the fact that the bed of the molten metal is sand, its natural one, are all contained in the sand-spun pipe, equally with the pit-cast one. The only feature of the manufacturing process of the sand-spun pipe which is common to other centrifugal processes is that centrifugal action enters into all of them. One great advantage, however, which the sand-spun pipe possesses over the pit-cast one, is that the former is free from gas cavities and non-metallic inclusions.

Preparation of Moulds.—The moulds are made on plain pneumatic jolters. There are four duplicate machines, each capable of handling loads up to 12 tons. The jolters are carried on reinforced concrete foundations constructed on piles. The foundations are isolated from each other and from the foundations of the building in order to minimise the transmission of vibration.

For pipe sizes of from 4 in. to 8 in. inclusive, three moulds at a time are jolted on one machine, while for sizes from 9 in. to 12 in. inclusive, two only are made. Hence, either two or three sets of moulding tackle are used in connection with each jolter.

The body patterns are centred with the socket-patterns by means of a tapered spigot and socket-joint, and as has been mentioned before, the whole pattern assembly is centred with the flask by means of the socket-end ring at the bottom and the sand-hopper at the top. When the flask has been filled with sand, the hopper is removed, the top end of the mould hand-rammed, and the groove for the bead formed by dropping the beader-plate over the pattern, and ramming this down until the plate is flush with the flask flange. The beader-plate is then removed, and the spigot-end plate placed in position and bolted there. The blacking hopper is then placed on the spigot-end plate and the mould flushed with blacking. This blacking hopper is fitted with a spring-loaded leather-faced valve, which on being depressed releases the blacking solution.

After the jolting operation has been completed the body patterns are withdrawn from the moulds by means of an electric winch, capable of lifting 60 tons. The flasks are moved from the horizontal to the vertical position in which the moulds are made, and *vice versa*, by means of hydraulically operated tilting tables. On the completion of the moulds the flasks are rolled by hand from the tilting tables to the adjacent gantry ; from there they are removed two at a time, by one of the three special manipulator type overhead cranes, to the mould-drying station, and there deposited on another gantry. Here the moulds are skin dried from the spigot-end by burners, using coke-oven gas. These burners are so designed as to inject large quantities of air through the moulds, in addition to the products of combustion. This arrangement enables the moulds to be rapidly dried without burning the blacking.

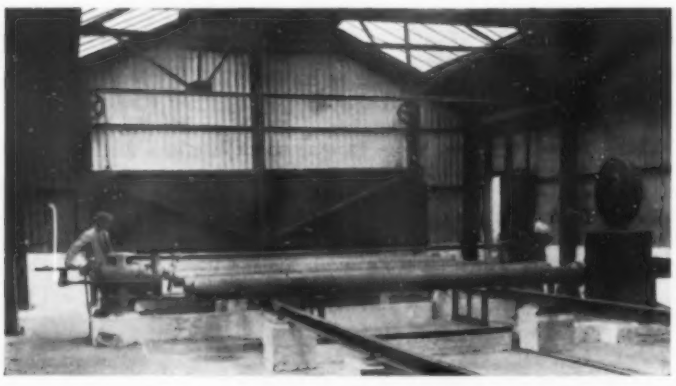
Spinners.—There are seven centrifugal machines or spinners, all duplicates except in respect of driving-pulley diameters, where some special speed condition is required. Each machine consists of a built-up steel box framework, rigidly bolted to a heavy reinforced concrete foundation, and contains two driving and two idle rollers upon which the flasks rest. The roller shafts are supported by heavy type roller bearings. Extensions of the driven roller shafts are fitted with brake-drums and the driving pulleys ; the brake shoes are Ferodo lined, and enable the rotating parts to be rapidly brought to rest. Two 15 h.p. motors drive each machine through belts to the pulleys previously mentioned. The motors are operated by three-phase 30-cycle current at 440 volts, and specially designed contactor gear, with remote control, enables both motors to be started or stopped simultaneously. The motor and roller speeds are 860 and 1,100 r.p.m. respectively.

The flasks are moved in and out of the spinners by means of hydraulically operated manipulator gear. This gear also operates a safety hood which encloses the whole machine whilst spinning proceeds.

The metal is poured into the mould at the spigot end, as has been previously mentioned. Each spinner is provided with its own tilting ladle, which is mounted on a carrier or bogie, and which in turn runs on rails on the platform of a weighing machine. Hence, as the iron is poured into the tilting ladle the weight is shown on the weighing machine dial. Therefore, the crane-driver, who also operates the ladle, merely pours a predetermined quantity of iron equivalent to the weight of the pipe that it is desired to cast. After the tilting ladle is filled the carrier is run forward into the casting position, and a signal lamp situated at the opposite or control end of the machine automatically indicates this.

A further signal lamp lights up as soon as the machine is up speed ; when these two lights appear the spinner-operator tilts the ladle by means of a hydraulic ram. Even distribution of the metal is complete within a few seconds of pouring, and spinning is continued for a period of approximately 1 min. per inch of diameter. By this time solidification has taken place, and the machine is stopped, the flask ejected, and a new one takes its place.

Weighing and Testing the Sand Spun Pipes.



As the machines are intended to work in pairs, the inlet and outlet gantries of two machines are adjacent to one another; hence, it is normally possible to put down and pick up two flasks at one time, and the special 10-ton manipulator cranes, previously mentioned, are arranged for doing this.

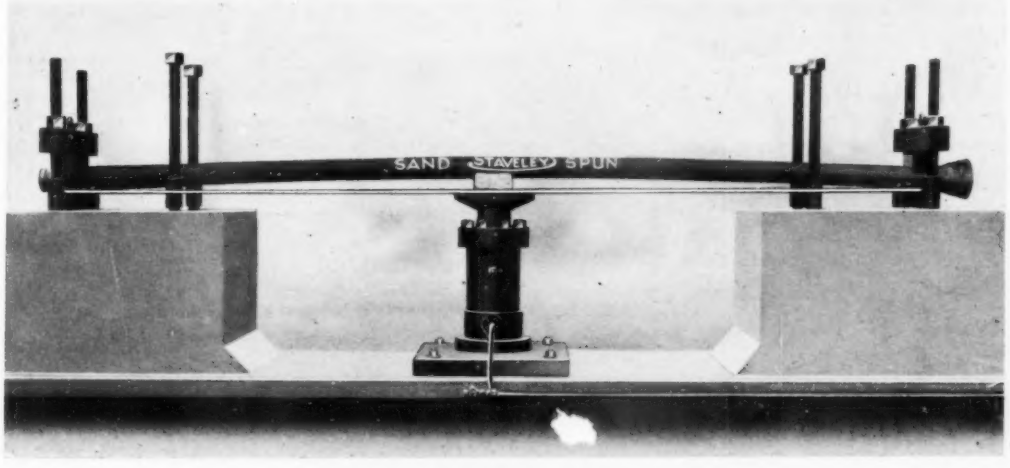
In this way the full flasks are transferred to the cooling gantry, which is of sufficient length to enable each flask to occupy 60-70 mins. in traversing it when the plant is running at full capacity. This ensures that by the time the pipe reaches the stripping station it has lost all colour of heat, and therefore cannot take any harm from exposure to the air. It is of interest to note that because of this method of controlled cooling, the percentage of bent pipes made since the plant started is infinitesimal. The pipes are stripped from their moulds by means of hydraulic rams.

When the flasks are in line with the stripper rams, which are arranged in pairs, they lie on a tilting table; this table can be tilted to an angle of 70° to the horizontal, hence when the pipes have been removed and the table tilted the sand falls out to a grating, which latter forms the entrance to the sand reconditioning plant.

to a coke-fired stove of the continuous type, the temperature of which, together with that of the tar solution in the adjacent tank, is under pyrometric control. After the pipe has reached the required temperature in the stove, it is run on to a suspended tray and lowered thereon into a bath of dehydrated tar solution. When sufficient time has elapsed for the coating to set, the pipes are passed out under an open crane gantry, where they are first stencilled, and then loaded for despatch or stock, as the case may be.

Cores.—The socket cores are made of oil sand on small jolt-squeeze machines of the Osborne type. These machines are fed from overhead bunkers, the sand used being first dried and cooled. It is then delivered in measured batches into small mixers, where the core oil is added in the required proportions. After the cores are stripped, they are placed on portable racks and transported by means of lifting trucks to one of the eight coke-fired core-drying stoves. Here they are baked, then removed from the stoves and finally delivered on similar racks to the spinning stations.

From the point where the pipes are stripped the sand enters a shaker conveyer and is delivered by it into a



Method adopted for testing the Pipes.

After stripping, the pipes are conveyed by transfer car to a long gantry running parallel to and partly below the jolting operating platform. From this gantry they may be diverted to any one of three other gantries situated at right-angles by means of specially designed turntables. These latter gantries lead to identical finishing units, each consisting of a grinding plant, weighing and proving unit, and dipping section.

Grinding Plant.—Slight flashes or other similar surface imperfections which, if present, are generally located at the pipe ends, are removed by means of ordinary pneumatic turbo-hand grinders. Internal grinding for the removal of the non-metallic matter is effected by means of electrically driven grinders, the grinding-wheel of which is mounted at the end of a long shaft. The pipe while it is being ground is carried on driven roller supports which rotate it in the opposite direction to that of the grinding-wheel.

The dust produced by the grinding operation is dealt with by a specially designed dust-extraction system, which removes it from the pipe at that end remote from the grinder. After the completion of this operation, the pipes are inspected, weighed, and proved, unless they are of the turned and bored variety, in which case this machining operation is carried out before proving.

Each pipe, whether it is to be inspected by the customer's representative or not, is visually examined, gauged, and hydraulically tested to the requisite pressure prescribed by the British Standard Specification, by the company's own inspection department.

After the pipe has passed inspection it is moved forward cooling drum. This drum is connected to the main dust-extracting system, and the cooling of the sand is effected by the passage of the incoming cool air. From the drum the sand passes to one of two duplicate elevators, which lifts it approximately 60 ft. and delivers it to a vibrating screen, where any foreign matter and sand aggregations are removed: these latter, together with such surplus sand as may have resulted from large additions of new sand, or from some irregularity in the working of the plant, are taken by belt-conveyer to a bunker outside the building for removal to dump.

The sand which passes through the screen is received in a storage bunker, whence measured quantities are taken by means of batch-hopper and placed in a Smith mixer. The required quantity of new sand, in the neighbourhood of 5 per cent., is added at this point, together with a measured quantity of clay wash of a known specific gravity. After mixing has proceeded for a sufficient time, the whole charge is transferred to a mill of the Simpson intensive type. From the Simpson mill the sand is delivered to a feeder, which in turn delivers it to an inclined belt. By means of this latter, a horizontal belt and a tripping belt conveyer, it is delivered into eight cylindrical feeder bins, arranged in pairs above the jolters, and is once more ready for use. As proper sand control is an absolute essential for the correct functioning of the plant, sand from both mixer and mill is tested for both moisture and strength continually while the plant is working. In addition, permeability tests, specific gravity tests of the clay wash, etc., are taken at frequent intervals during each shift.

(*Continued on page* 32).

Reviews of Current Literature.

Metallurgy.

THE literature devoted to metallurgy is rich and, for those concentrating on this science, very comprehensive: but there is a scarcity of books to which the engineer can turn for brief, reliable information respecting the metals and alloys now used in engineering construction. It is to supply this need that this present book has been primarily written.

The increased development and wide application of new materials, embracing both ferrous and non-ferrous metals and alloys, necessitates some metallurgical knowledge on the part of the engineer. The repeated demands for materials capable of withstanding high-duty conditions have been largely responsible for the remarkable progress in metals during recent years. Great advancement has been made in developing materials to withstand high temperatures, corrosion resistance, and high resistance to fatigue. The demand for lightness combined with weight has also been the subject of much thought, and the progress of the light-alloy industries is a good indication of the success that has resulted. Many of these new materials, however, depend upon suitable heat-treatment for those qualities that give increased properties, and unless some knowledge of the effects of heat-treatment is possessed by the engineer the value of the special material is unlikely to be fully developed.

The author deals with a very comprehensive subject in 284 pages, and apart from reference to Bessemer steel, which is not manufactured in this country, the book is useful from an engineer's viewpoint. It is divided into seven chapters, in the first of which he deals with iron. Commencing with the ores, the reaction in the blast-furnace during the manufacture of pig iron is briefly described. In addition to the effect of the constituents of cast iron on the properties of the material, reference is made to various alloy cast irons and to malleable cast iron.

In view of the wide range of steels now available the author has devoted considerable space to this subject, chapter two dealing with the manufacture, properties, and uses of steel; stainless and rustless steels are discussed in chapter six, while the important features of special steels and other ferrous alloys are separately discussed in chapter five. The constitution of metallic systems, which is considered in another chapter, is a valuable addition, since it enables the reader to understand better the fundamental principles involved when two or more metals are associated to form an alloy. The technical principles involved in heat-treatment and their practical application offer scope for considerable discussion, but in a chapter on the subject the author has assembled useful information that is applicable to modern developments. The latter part of the book is devoted to non-ferrous metals and alloys, in which reference is made to all the newer alloys that are being increasingly employed.

This is a very useful book, not only to the engineer but to the designer and to the draughtsman. In addition to brief information on metallurgical principles, which the user of metals can read with advantage, the manner in which questions are discussed will appeal to the reader because information is conveyed in an interesting form. The book is exceedingly well illustrated, the micro-photographs being particularly good, and there is no doubt that it will appeal to engineers and others desiring an elementary knowledge of metallurgy to supplement their practical experience.

By EDWIN GREGORY; published by Blackie and Son, Ltd., 50, Old Bailey, London, E.C. 4. Price, 17s. 6d. net.

Overhead Transmission Lines.

THE combined properties of lightness and good conductivity have made aluminium a serious competitor of copper in the construction of long-distance transmission lines. Weight for weight it has about twice the conductivity, and its use for overhead transmission lines permits material economy in construction and maintenance, and reduces the number or height of supporting towers for a given clearance. In addition, an aluminium conductor of given electrical capacity has greater surface, and consequently lower corona loss than a copper conductor of similar capacity. The use of aluminium for this purpose has been developed to a considerable extent during recent years, particularly in the form of steel-cored aluminium conductors, which have been adopted for the British National "Grid." This great 132,000-volt network, now in course of construction, will be one of the most extensive ever erected, and the primary lines will contain over 12,500 miles of steel-cored aluminium.

Valuable information on the subject of steel-cored aluminium conductors has been prepared by The British Aluminium Co., Ltd., which is published in this little book of 96 pages. It consists of a series of data sheets that gives, in a very concise form, much valuable information on the subject, from various constructions of conductors to their erection, and includes various types of joints, sag calculations, etc., together with British and some foreign countries, regulations regarding overhead transmission lines.

Transactions of the Institution of Engineers and Shipbuilders in Scotland, Vol. LXXV., Part VI.

THIS section of the transactions contains the discussion which resulted from the paper given by Sir Herbert Austin, K.B.E., entitled "Workshop Practice in Automobile Engineering." In reply to the discussion, Sir Austin made some interesting comparisons between America and this country in regard to economical production, and stressed the need of reducing costs in the motor industry in this country.

Included in this part are papers and discussion on "Corrosion in Hulls of Merchant Ships" and "Recent Improvements and Reconstruction Works in Glasgow Harbour." The authors of the former, J. Montgomerie, D.Sc., and W. E. Lewis, B.Sc., appreciate the importance of metallic corrosion as an industrial factor, and they come to the conclusion that the problem of corrosion on the external surfaces of merchant ships is primarily connected with the condition of the surface in respect of the amount of mill scale still adhering to it before the paint is applied. They propound an electrolytic theory as an explanation of the facts of corrosion. This paper resulted in considerable discussion.

The improvement and development of the River Clyde during the past 50 years is one of the romances of maritime engineering in this country, but in his paper Mr. A. C. Gardner referred more particularly to quite recent improvements, confining himself to works which have been in progress simultaneously with the construction of the new dock at Shieldhall.

British Standards for Copper for Electrical Purposes.

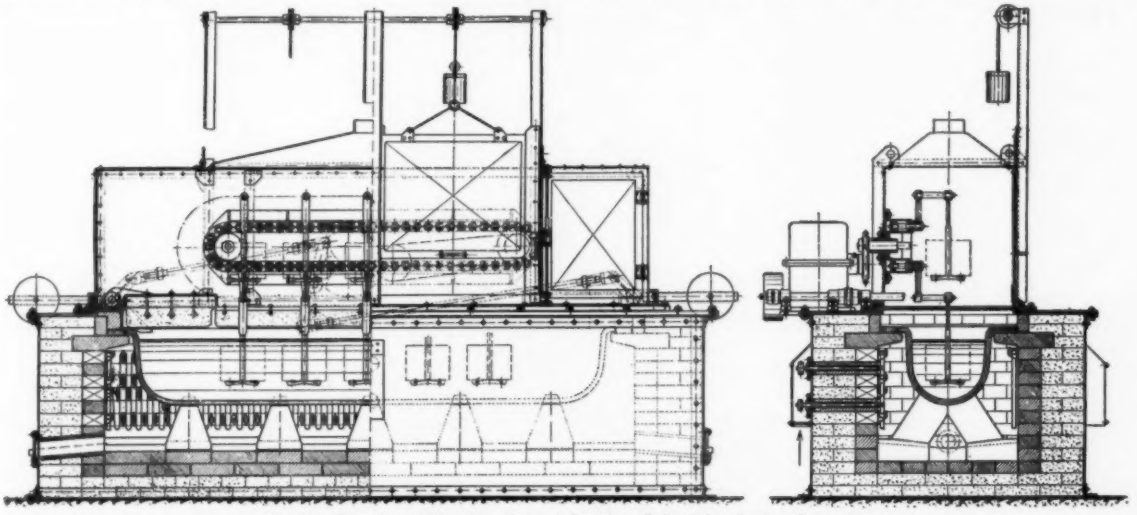
TWO new British Standard Specifications for copper deal respectively with Plain Dead-soft Copper Strip, Bars, and Rods for the windings of electrical machines (No. 444–1932), and Copper Commutator Bars for electrical purposes (No. 445–1932). Both specifications include requirements for conductivity and tensile properties, whilst in the case of the commutator bars Brinell hardness tests and Shore sclerescope tests are given for application at the option of the purchaser. The selection and preparation of samples for the electrical and mechanical tests is dealt with, and clauses relating to testing procedure are included.

The specifications do not standardise sizes for the bars, rods, and strip, but tolerances on width and thickness, and in the case of commutator bars length and angle, also, to apply to the nominal sizes ordered by the purchaser, are specified.

Recent Developments in Tools and Equipment

A New Electric Automatic Hardening Furnace.

THE bath method of heating possesses several advantages; particularly is it effective in maintaining atmospheric control, because all air is excluded from the surfaces of the charge during the time of heating. This method of heating has been developed in various types of lead and salt baths. The temperature of the lead bath is limited to about 870° C., because the lead readily volatilises above this temperature, although a carbon layer on the surface of the metal will reduce this trouble. The salt bath, on the other hand, may be used at temperatures up to about 1,200° C., providing a suitable combination of salts is used. In addition to higher operating temperatures the salt bath has the further advantage over the lead bath of causing a thin film of the salt to adhere to the charge, which protects the surfaces from the air during its movement to the quenching bath. Electric heat has been applied to both types of baths for many years; in fact, the application of electric heat to salt baths preceded the development of the electric furnace; it is, therefore, of interest to note a new automatic hardening furnace of this type which is electrically heated. Designed by E. Fr. Russ, and manufactured by the "Industrie" Elektroofen G.m.b.H., Cologne, this furnace maintains and accurately records hardening temperature, charging time, duration of heat, and discharging time. It eliminates rejects, a point of considerable importance in the hardening of otherwise finished parts. This furnace has been designed for hardening steel parts requiring high quality and uniformity of treatment. It provides for a high running output with low labour charges.



Sectional and outside elevation of electric salt bath hardening furnace.

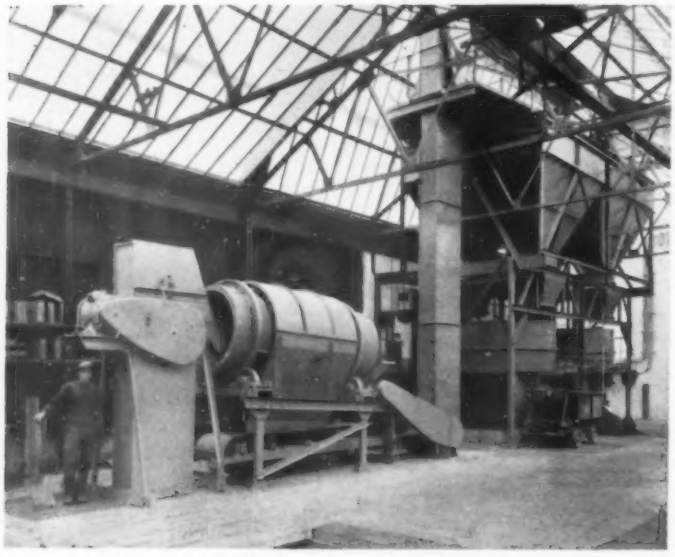
The furnace comprises a metal trough, in which the hardening salt is raised to a maximum temperature of 950° C. It is heated from the outside by means of a resistor, a long, metallic ribbon suspended in loops, with 70 kw. input. The articles to be hardened are placed in receivers suspended from a conveyer chain, which automatically lowers them into the bath. Upon completion of the hardening the finished parts are automatically raised from the bath while new receivers, which have been charged in the meantime, are immersed. The drive is effected by a motor controlled by a timing clock over a relay. This motor, over an intermediate wormwheel, drives a shaft armed with an eccentric, which actuates a rod linkage and thereby raises the lids capping the receiver entry and exit openings at the two ends of the trough. As soon as the lids are in their highest position a clutch automatically connects the wormwheel shaft with a loose sprocket, which then starts the conveyer over a flat-link chain. When the newly charged receivers have arrived at their lowermost position in the bath the driving sprocket is automatically disengaged. In the meantime the eccentrics has continued its revolution far enough to cause both lids to drop back in place. At this moment a bell rings and a signal lamp flashes up, to notify the operator that the finished articles must be removed and the receivers recharged. The hardening process lasts until the moment set on the timing clock. As soon as one cycle is ended a new one automatically commences.

The hardening temperature is measured by thermo-couples immersed in the bath. The thermo-e.m.f. at the same time automatically regulates the heating current by actuating relays and contactors over a temperature regulator. The latter shows the bath temperature, and permits any desired temperature to be set by means of a pointer. The temperature of the heating ribbon is ascertained and regulated in the same manner. Positive knowledge therefore prevails at all times about the relation between the heating and working temperatures, and both temperatures are continually recorded.

In continuous service the furnace has a capacity of case-hardening from 45 lb. to 110 lb. of parts every 15 to 20 mins., the exact time and capacity depending upon the shape and size of the work and the number of pieces that can be simultaneously placed in the furnace. On an average a daily output of 5,500 lb. of small parts, such as bevel or spur-gears, can be dealt with. Originally, the furnace was designed for hardening 360 gears per day, each weighing 3·3 lb. Since then, however, it has been found that this amount of work can be handled in a much shorter time than had been assumed, with the result that the furnace became available for additional work. The weight of the receivers is very low, amounting only to 44 lb. within the bath. This fact restricts current consumption to the moderate figure of about 140 to 200 W. per lb. of steel treated, including radiation losses and unavoidable waits between charges.

Foundry Improvements at Kilmarnock

GREAT advances have been made in foundry work during recent years, and modern methods are well illustrated by improvements that have just been carried out in the light-castings foundry of Glenfield and Kennedy, Ltd., of Kilmarnock. Within the past year or two the whole of the extensive machine shops of this company have been re-equipped with modern plant. Modernisation has now been effected in the light foundries, which are engaged principally in the production of castings for sluice valves, hydrants, and other waterworks fittings, while similar methods obtain with the firm's heavy foundries for handling single castings up to 30 tons in weight.



Sand conditioning plant at the light castings foundry of Glenfield & Kennedy Ltd.

The work in the light foundry is of repetition character, and a central sand-conditioning plant has been installed to ensure that the sand used by every moulder is of the same composition. In this plant the sand is first taken by a continuous elevator to an inclined rotary screen, fixed a short distance above ground level, which breaks it up and separates any extraneous material. The screened sand then travels on a short conveyer under a magnetic separator, which removes the remaining metal, and passes into the boot of a second high vertical conveyer, which raises it to a short horizontal distributing conveyer above large sand-storage bunkers. Each of these is divided into two compartments, for green sand and dry sand respectively, and discharges below to a mixing mill: that is, the whole compartment consists of two divided storage bunkers with hopper bottom and two mixing mills, while any water added to the latter is measured by a meter, the correct amount having been determined by laboratory analysis and also by practical experience. In this manner any desired mix of sand is obtained, while, as already stated, every moulder has exactly the same material: a highly important matter in ensuring uniform high-grade quality of the finished castings, when the thickness of metal does vary appreciably.

Notable also is an installation of the "Osborn" type roll-over moulding machines, one of the latest type of jolt rammers available, which is suitable for repetition work, or when only small numbers of castings are required from different patterns. Further, the machine is of the portable type and is moved about as required, being connected up by a flexible hose to a compressed-air system, and taking moulding boxes up to 54 in. long by 24 in. wide by 12 in. deep. Other interesting installations include "Ronceray" hydraulic-squeeze moulding machines, which make moulds from double-sided plate patterns without the use of a moulding box; that is, forming the two parts of the mould simultaneously, drawing the pattern, closing the box, and then pushing the mould completely through after the cores are inserted.

The Plastic Deformation of Metals.

THE twenty-second annual May lecture of the Institute of Metals was delivered by Professor Dr. F. Körber, Director, Kaiser Wilhelm-Institut für Eisenforschung, Düsseldorf, on May 11, in the Hall of the Institution of Mechanical Engineers. Professor Körber based his remarks on the results of a series of investigations which had been conducted at Düsseldorf during recent years on the plastic deformation of metals. He dealt with the stress relationships, and also with the course of the flow of the material which arose during the most important of the mechanical shaping processes. Discussions were entered into on the conditions requisite for the commencement of plastic flow, and also on the possibility of drawing conclusions from the resulting flow phenomena as to the distribution of stress in the material at the inception of deformation. The disturbances in the material in consequence of the more marked deformations in drawing, extrusion, and rolling were traced by a suitable method of investigation. The results were compared with the deformation structures obtained by X-ray methods. The knowledge of the deformation processes so obtained enabled conclusions to be drawn as to the energy or power used in the shaping operations. An exact analysis of the course of deformation in the transition zone led to reliable estimates of the internal losses during the alterations in form. Quantitative treatment of the stress relationships which occurred in the zone of deformation was possible in so far as the pressure created at the surfaces of contact between the tool and the material was known by actual measurements. From the results of determinations along the roll gap of the pressure between the rolls and the stock being rolled a complete quantitative presentation of the distribution of stress in the transition zone between the rolls had been formulated.

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yield ratio is required or sections greater than about 2 in. in diameter are to be treated, water-quenching should be employed. It is desirable to limit the carbon content to a maximum of 0·45% in the water-quenched steels. In counteracting mass effect an increase in the manganese content is much more effective than an increase in the silicon content.

Steels lying at the extreme limits of the usual specification for silico-manganese spring steels have been included in this investigation. It is shown that a low manganese content is always associated with a low yield ratio, and a high manganese content with a high yield ratio. Fatigue tests carried out on three steels in the oil-hardened and tempered condition show that a steel with a high-silicon, low-manganese content, and a low yield ratio, is less affected by surface irregularities than are two steels with higher manganese contents and higher yield ratios. On the other hand, the steel with a low manganese content is much more affected by surface conditions due to heat-treatment than are steels higher in manganese and lower in silicon.

An increase in the silicon content leads to an increased tendency to surface decarburisation, while an increase in the manganese content has the opposite effect. These two elements affect surface decarburisation in a direction opposite to their effect on the tendency of a steel to scaling.

The Adhesion of Electrodeposited Nickel to Brass.

IN the plating of brass for decorative or protective purposes, peeling of the deposit sometimes occurs either during nickel plating or polishing, or during the subsequent chromium plating where this is applied. The forces operating to cause peeling during chromium plating appear to be greater than those which tend to produce this type of failure during nickel plating or polishing, and chromium plating has consequently come to be regarded as a drastic test of the adhesion of thin nickel coatings.

The difficulties of obtaining good adhesion of nickel to brass in decorative plating are principally connected with the necessity for preserving the polish of the brass, since it is known that by the use of suitable etching methods, which cause a pronounced roughening of the surface, adherent coatings having a degree of adhesion which is in general approximately equal to the shear strength of the basis metal can readily be produced. If, however, the smooth finish of the brass is materially destroyed heavy polishing is necessary subsequent to nickel plating, and unless nickel deposits of a greater thickness than is normally considered necessary are applied, there is considerable risk of laying bare the brass at exposed areas, such as projections and edges, and, in any case, the deposit is liable to be rendered very thin in such areas, and its protective power consequently considerably reduced. High finishing costs and reduction of protective properties thus prevent the general adoption of drastic etching methods in decorative plating.

With the object of determining the more important causes of poor adhesion of nickel electrodeposited on brass for decorative purposes, and of attempting to evolve methods of treating polished brass surfaces so as to secure a high degree of adhesion without materially destroying the finish, work was undertaken at the Research Department, Woolwich, for which the British Non-ferrous Metals Research Association provided funds. This work is described in a report, submitted to the Electroplaters' and Depositors' Technical Society, by A. W. Hothersall, M.Sc. Problems connected with the preliminary operation of removing grease from metal surfaces have been considerably studied in recent years, and this aspect of the subject has not been included in this investigation.

In this investigation it is shown that the nature and degree of adhesion of electrodeposited nickel obtainable to brass surfaces cleaned by methods not involving etching have been studied, and the degree of adhesion has been found to vary according to the nature of the brass surface. Thus, whilst a relatively high adhesion was obtained to filed or machined brass, only a slight degree of adhesion (such that the deposit could be pulled off with the fingers) was found in the case of emeried brass. The results obtained by the tests applied do not, however, indicate the true adhesion as the test-pieces invariably failed in the surface layers of the brass and not at the deposit/brass interface. In the majority of cases heat-treatment of the nickel-coated specimens at 250° C. for two hours was found to improve very considerably the degree of adhesion of nickel deposits to surfaces not subjected to etching during cleaning, and a similar improvement in adhesion was generally obtained by the preliminary deposition of a layer of copper from the acid sulphate solution followed by deposition of nickel. By these methods fairly strongly adherent deposits could be formed on emeried brass, and with their use the effect of progressive etching of an emeried surface was studied. The degree of adhesion was found to increase gradually with the degree of etching, and it is concluded from this, and from the results referred to above, that the poor adhesion of electrodeposited nickel which is obtained on unetched emeried brass is due partly to embrittlement of the surface layers by adsorption of hydrogen and partly to the weak condition produced by the emery treatment.

In the case of buffed brass, it has been found that the material which is particularly weak inherently, and which is principally susceptible to hydrogen embrittlement, is confined to an extremely thin surface skin, probably less than 0·0005 mm. in thickness, and that removal of this skin by means of suitable etching treatment before deposition of nickel results in the production of adherent deposits. Etching by means of nitric acid or mixtures containing nitric acid has been found to be undesirable, as the process cannot be satisfactorily controlled. Anodic etching in a suitable solution, however, affords a means whereby polished brass surfaces may be sufficiently etched to ensure the production of adherent nickel deposits without noticeably dimming the lustre.

Two solutions have been used for the anodic etching of brass—a potassium-cyanide solution, and a solution containing citric acid and ammonium citrate. Treatment of buffed brass at 10 amps. per sq. ft. for about half a minute has been found to be sufficient to ensure the production of highly adherent nickel deposits on a number of different types of brass without appreciably affecting the polished appearance.

Catalogues and Other Publications.

Bradley and Foster, Ltd., Darlaston, Staffs., have sent us a brochure giving information regarding a new range of refined alloy pig irons containing varying proportions of nickel chromium, vanadium, titanium, etc. These refined alloy irons are recommended for all castings required to possess heat-resisting, wear-resisting, and corrosion-resisting properties. Much useful information is given in this brochure.

The recent installation of new plant at Sir W. G. Armstrong-Whitworth and Co. (Ironfounders), Ltd., Close Works, Gateshead-on-Tyne, for the production of iron for high-duty grey and malleable iron castings, has enabled the firm to produce what is termed New Process Iron. It is claimed that this will revolutionise previously conceived ideas of grey and malleable iron. A very attractive brochure has just been issued giving technical information regarding the range of irons produced by this process.

We have received a copy of the first issue of a magazine entitled *Sands, Clays, and Minerals*, which is to be published quarterly by Mr. A. L. Curtis, Chatteris, England. It contains many interesting articles, which include: "Practical Sampling of Ores," "Sand in British Industry," "Slate," "Manufacture of Portland Cement," "Lithographic Abrasives," and "Precious Stones." The magazine will be published quarterly, and the subscription is 5s. per annum.

A useful booklet has recently been published by the English Steel Corporation, Ltd., Vickers Works, Sheffield, dealing with A.W. Small Tools. It gives full particulars regarding stocks and dies, hand, machine, master and boiler-stay taps; solid, spring, and split dies; hand and machine chasers; tap wrenches, etc. When applying for a copy, readers should ask for Screwing Apparatus, Section No. 6.

The April issue of *The Nickel Bulletin* contains an informative article on "The Manufacture of Gears" from the practice of David Brown and Sons, Ltd., of Huddersfield. Nickel-chromium steel spades and shovels are discussed in another article, and with the useful abstracts and references which are a feature of this publication the issue is noteworthy.

Rustproofing, Ltd., 11, Thames Street, Sunbury-on-Thames, have sent us some leaflets regarding recent developments in connection with the rustproofing of iron and steel. They refer more particularly to the sherardising process, spray sherardising, slatering and leadising as effective means of reducing the corrosion of metals and alloys. Copies are available on application.

In addition to "Eternite," which is used as a box compound for case-hardening, G. W. B. Electric Furnaces, Ltd., of Elecfurn Works, North Road, Holloway, N. 7, are manufacturing and marketing an open-hearth compound known as "Kleenard," and an anti-carburising clay known as "Nokase." A folder which we have received gives particulars of these specialities.

Some Contracts.

The British Mannesmann Tube Co., of Newport, Mon., has obtained an order from the Iraq Petroleum Co. for the supply of about 26,000 steel poles in connection with the desert pipe-line scheme.

The Clyde Crane and Engineering Co., Mossend, have secured a contract for the supply, delivery, and erection of one 60-ton overhead electric travelling crane for the Tongland power-station, and one 50-ton overhead electric travelling crane for the Glenlee power-station, for the Galloway Water Power Co.

The Westinghouse Brake and Saxby Signal Co., Ltd., London, has received orders for rectifier sets for trickle-charging tripping batteries for 132 k.v. sub-stations from the Central Electricity Board.

John I. Thornycroft and Co., Ltd., have been awarded a contract by the Admiralty for the construction of a river gunboat for service in China.

The Radio Communication Co., Ltd., London, have secured a contract for the supply and erection of two 500-ft. lattice steel masts for the British Broadcasting Corporation. These masts are to be erected at the West Regional Station, Watchet.

The Clydeside Constructional Co., Bridge of Weir, have received an order for the construction of an intake chamber, screening chamber and house, a compensation chamber and house, a mass-concrete pier, and other work at Loch Recawr. The order is stated to be valued at £6,000.

Hall, Russell and Co., Footdee, Aberdeen, have obtained an order for a steamer with a carrying capacity of 1,100 tons from Ellis McHardy, Ltd., Aberdeen.

Messrs. H. J. Cash and Co., London, have been awarded a contract for the installation of steam plant, calorifiers, pumps, etc., at St. Nicolas's Hospital and Woolwich Institution. The contract is stated to be valued at approximately £9,000.

Messrs. Babcock and Wilcox and the Underfeed Stoker Co. have each been awarded contracts for the installation air-heater for the boilers at the generating station at Croydon.

Messrs. Cammell Laird and Co., Ltd., Birkenhead, have secured an order for the construction of a twin-screw sand pump dredger for the Mersey Docks and Harbour Board.

Messrs. Henry Robb, Ltd., Leith, have obtained an order for a motor coaster for the South of England. The vessel will have a carrying capacity of 200 tons, and will be fitted with Diesel engines.

Edwin Danks and Co. (Oldbury), Ltd., have been awarded a contract for the installation of Lancashire steam boilers at Lambeth Hospital.

Messrs. Cowans, Sheldon and Co., Ltd., Carlisle, have been awarded a contract for two steam 30-ton breakdown cranes for the India Store Department, at the price of £6,367.

Messrs. Ruston-Bucyrus, Ltd., Lincoln, have received from Messrs. L. J. Speight, Ltd., London, an order for five of their No. 4 excavators, which we understand are intended for work in connection with the development of the Grand Union Canal.

Messrs. Mirrlees, Bickerton, and Day, Ltd., have secured an order to the value of £9,000 for the supply of two Diesel engines for Barnstaple Town Council.

The English Electric Co., Ltd., of London and Stafford, has received from the Corporations of Preston, Hull, Wallasey, Bournemouth, and Northampton orders for an aggregate of 35 double-deck and nine single-deck omnibus bodies. The same company has also received from the Southend Corporation an order for two double-deck trolley omnibuses, and from the Notts. and Derby Traction Co. an order for 10 single, deck trolley omnibuses.

The Westinghouse Brake and Saxby Signal Co., of Chippenham, has received a contract from the Metropolitan Railway Co. for the installation of a centralised traffic control system, covering the new extension under construction between Wembley and Stanmore.

Negretti and Zambra have received a contract to supply eight sets of dial thermometers, dial draught gauges, and multi point electrical resistance thermometers for the new boilers at the Barking power station.

The D.P. Battery Co., Ltd., of Bakewell, have received two contracts for telephone exchanges in the London area. One, for the London Trunk Exchange, covering the supply of two batteries, each having a capacity of 7,800 ampere hours, was placed through Standard Telephones and Cables, Ltd. The other, for the Kensington Exchange, covering two batteries having a capacity of 9,890 ampere hours, was placed through the General Electric Co.

The Metropolitan Cammell Carriage, Wagon, and Finance Co., Ltd., of Saltley, have received an order from the Birmingham and Midland Motor Omnibus Co., Ltd., for ten 52-seater double-deck bus bodies of special all-metal construction.

Roneo, Ltd., have obtained a contract for the supply of a large quantity of shelving for the library of the Palais des Nations, Geneva. The value of this contract is stated to be between £40,000 and £50,000.

The Avonside Engine Co., Ltd., of Bristol, have received an order for two new boilers for G and H class locomotives of the Metropolitan Railway.

Morris Commercial Cars, Ltd., Soho, Birmingham, have received orders for 22 vehicles for Holland, 16 for India, 20 for Irish Free State, 4 for Shanghai, 6 for Java, and various lorries for Cairo, St. Lucia, Rhodes Island, and Denmark.

The North British Locomotive Co., Ltd., Springburn, Glasgow, have booked an order for four locomotive boilers for the South Indian Railway.

Personal.

Lord Falmouth having requested to be relieved of his duties as managing director of the English Steel Corporation on account of other engagements, Commander C. W. Craven, O.B.E., R.N., has been elected to fill the appointment. Lord Falmouth has agreed to become the deputy-chairman of the Corporation.

Mr. Ernest A. Smith, A.R.S.M., M.Inst.M., has been appointed to the technical staff of Messrs. Oakes, Turner and Co., Ltd., of Sheffield, the affiliated northern firm of Messrs. Johnson, Matthey and Co., Ltd., the well-known precious-metal refiners.

Mr John Drummond Frier, lecturer in mechanical engineering to the Northampton Polytechnic Institute, London, has been appointed head of the Mechanical Engineering Department of Coventry Technical College.

Manchester Offer Scholarships.

The Manchester City Council is again offering a number of scholarships tenable in the Faculty of Technology of the University of Manchester. Successful candidates are required to follow a full-time course leading to the degree of Bachelor of Technical Science in the College of Technology and matriculation, or its equivalent, is an essential qualification. For students who have been engaged in industry, and who have attended part-time day or evening classes, the scholarships are of the value of £100 per annum, while for students leaving secondary or central schools the value is £60. Both classes of scholarships are tenable for three years.

Business Notes and News

New Coke-oven Plant at Beckton Gas Works.

The new coke-oven plant at the Beckton Works of the Gas, Light, and Coke Company, recently officially started by the Prince of Wales, consists of 60 Koppers twin-flue combination ovens. They are designed to carbonise 1,200 tons of coal per day, and the layout of the installation has been arranged to facilitate subsequent extension to enable an ultimate capacity of 4,800 tons of coal to be treated per day. Each of the present ovens is 40 ft. long, 14 ft. high, and approximately 18 in. wide.

This installation embodies the latest features in coke-oven design. Each oven is of the vertical-flue type, and above each flue openings are arranged for inspection and regulation. The air for combustion is pre-heated, and an important feature of the Koppers system is the separate regenerators for each oven. Incorporated in the design is an arrangement for regulating both the air and the chimney draught to each oven, while other important features include self-sealing doors and brick-lined off-takes.

Andrew Laing Lecture.

In our October issue of last year reference was made to the announcement by the North-East Coast Institution of Engineers and Shipbuilders that the memory of the late Mr. Andrew Laing was to be perpetuated in the North-eastern district by an annual memorial lecture. This has been made possible through the munificence of the Misses Jeanie and Catherine Laing, sisters of Mr. Andrew Laing, who have founded a special fund for the purpose.

It was hoped to make arrangements for the first Andrew Laing Lecture to be read during the 1931-2 session of the Institution, but time has been too short. We are informed, however, that the first lecture will be delivered during the course of the 1932-3 session by the Engineer-in-Chief of the Fleet, Vice-Admiral Sir R. W. Skelton, K.C.B., C.B.E., D.S.O. The exact date of the reading of the lecture will be announced in due course.

A Smoke Problem Solution.

Considerable research work has been applied to the smoke problem in view of which it is of interest to note that a method of burning coal in a mill furnace has been evolved which is claimed to provide a solution. It is the result of long and costly experiments by Mr. George Clark, of the North British Steel Works, Sheffield. The principle of the method is, apparently, a control of the combustion, volume, and pressure of the gases inside of the furnace in order to effect complete combustion. By correct manipulation the smoke is retained in the furnace until fully consumed.

In addition to effecting a cure as far as smoke is concerned, the method is claimed to result in a considerable reduction of fuel, due to the combustible products of the fuel being more fully utilised. The method has as yet only been applied to one type of furnace, and while there is no proof that it will provide a solution for other types, obviously, if similar control can be effected, it should apply to other furnaces. Apparently any ordinary type of furnace with a brick bottom can be adapted to employ this new method.

Messrs. Davy Bros.' Agreement with American Company.

Messrs. Davy Bros., Ltd., of Park Iron Works, Sheffield, inform us that under an agreement recently entered into they are the sole manufacturing agents and representatives of The Watson-Stillman Co., of New Jersey, for Great Britain, and possess sales rights for most of Europe, consequently they are now in a position to supply any item of the Watson-Stillman range of products, including:—Hydraulic plastic moulding presses for a wide range of purposes—plain, heating, drilling, semi-automatic, tilting head, and angle moulding types; hydraulic extruding and straining presses, for insulating materials; hydraulic presses for wheel forcing, flanging, scaling, lead extrusion, etc.; and accessories.

The Watson-Stillman Co. recently purchased the business of The Burroughs Co., of U.S.A., and thereby added a further range of high-class products to their list of plastic moulding equipment. The effect of this agreement added to the wide experience of Messrs. Davy Bros., Ltd., in the manufacture of hydraulic presses enables them to supply plastic moulding machinery embodying the latest designs and improvements.

Catalyst Furnishes Final Step in Making Zinc Process Successful.

Remarkable improvements in the Maier process for the reduction of zinc ores by the use of natural gas were announced by R. S. Dean, chief engineer, Metallurgical Division, United States Bureau of Mines, at the meeting of the American Zinc Institute in St. Louis, Mo., recently. These improvements, which it is believed furnish the final steps in making this radically new zinc process successful, are the result of further experimental work. A contact material has been developed whose mere presence makes reactions of the new zinc process speed to completion.

The difficulties encountered in large-scale experimentation on the process have been overcome by the use of this catalyst, which is placed in the retort just before the gases enter the condenser. This catalyst, whose composition has not been fully revealed, causes the complete elimination of oxidising gases even when the process is operated at higher temperatures and rates than heretofore possible.

The essential features of the process so far developed are:—Continuous downward flow of calcine through a metal retort at temperatures of 1,050—1,100° C.; concurrent flow of natural gas to secure intimate contact with calcine; and treatment of gases resulting from reduction with excess methane in the presence of a special catalyst.

Development of the Maier process is the outcome of fundamental studies of metallic oxides begun by the Bureau of Mines some years ago. The success of the experimental work is largely due to the application of precise knowledge of chemical fundamentals, a field in which the Bureau's Berkeley station has specialised. Costs of reagents, thermal economies, maintenance, labour, and recovery of by-products, together with the quality of the zinc produced and lower costs of equipment, are all favourably influenced by the new process.

Building Exhibit in Thames House.

A display, having a special interest to architects, builders, and contractors, has been organised by the Imperial Chemical Industries in Thames House, Millbank, London, S.W. 1. The display is arranged so as to indicate the application of the many products of this company to buildings. The use of non-ferrous metals in domestic architecture is shown by wall-panels of phosphor-bronze and a ceiling of Cupro-nickel. In addition to special wall-covering, paints and varnishes, interior fittings and furnishings of moulded plastics, and a display of all types of electric-light fittings, pendants, wall-brackets and standard lamps, a wide range of photographs, plans, etc., of welded constructional work is displayed. The advantages of welding are undoubtedly becoming recognised for house construction, as not only does the welded-frame building involve a saving of some 20% in weight of steel, but it eliminates the noise associated with riveting. Amongst other constructional products exhibited are steel tubes and spheres especially designed for the construction of cheaper light-steel structures.

Presentation of the Kelvin Medal.

What is generally considered to be the highest honour that could be conferred on a member of the engineering profession, the Kelvin Medal, has been presented to the Marchese Marconi. In making the presentation in the Great Hall of the Institution of Civil Engineers, Lord Rutherford traced the history of electrical waves and their application to useful purposes. In that work, he said, no man had done more than the Marchese Marconi, who commenced his investigations in Italy in 1895, but had come to England to pursue them. In accepting the gift the Marchese Marconi said that Kelvin's study of the oscillatory discharge of the Leyden jar had helped towards an understanding of high-frequency electrical phenomena which formed the basis of wireless transmission. To him, Lord Kelvin had extended unfailing friendship and advice.

The first battery of coke-ovens to be heated by blast-furnace gas in this country is now in operation at the Scunthorpe Works of Messrs. John Lysaght, Ltd. This new plant is now carbonising over 1,000 tons per day of washed crushed coal, and consists of 47 Becker ovens heated by cleaned, cold blast furnace gas. The whole of the by-product coking installation was designed, erected, and put into operation by the Woodhall-Duckham Vertical Retort and Oven Construction Co. (1920), Ltd.

Some Recent Inventions.

Heat-treating Rails.

MANY methods have been devised for reducing the temperature differences that exist in a rail or other massive steel body which has been rapidly cooled below the critical range. A recent method is to immerse the rail in a highly heat-conductive medium, such as a molten lead bath, at a temperature above the "blue-heat" zone (ordinarily between 200° and 300° C.), and below the critical range, with the object of reducing the temperature differences quickly. Much of the interior of the rail, particularly the head, will still be above the blue-heat zone, so that the reduction of the temperature differences diminishes the chances of permanent defects from strains produced by the differences. The rail may be taken from the bath and then tempered in a furnace at 1,000° F., or the tempering may be effected in the lead bath by prolonging the immersion period.

362,439. BETHLEHEM STEEL CO., Bethlehem, Pensylvania, U.S.A. (Assignees of E. F. Kenney, Bethlehem, Pennsylvania, U.S.A.)

Metal Cores in the making of Hollow Bars.

IN making hollow metal bars or pipes, such as borers, stay-bolts, or hollow shafts, by forging or rolling a hollow blank on a metal core and then removing the core, a steel alloy core is used, having no transition point or a transition point below that of the steel of the blank, and the composite bar, after reduction, is cooled from a temperature above the transition point of the bar to a temperature below that point, but above the transition point of the core, and the core is withdrawn when the temperature falls between these limits. The expansion of the bar during transformation from gamma to alpha steel separates the blank from the core which can thus be easily removed without applying tension. A suitable core is formed of a steel alloy containing nickel, chromium, manganese, or silicon, or a combination of these elements. The temperature required for finishing the rolling may be above the transformation point of the bar, or the composite blank may be subsequently heated to that temperature, preferably electrically. The cooling from this temperature may be effected in water, oil, or air. Before the blank is heated for the reduction process, the ends of the core and blank may be partly or entirely connected by welding, etc., so as to vary the supply of air in order to obtain a film of oxide between the surfaces during heating, to act as a lubricant and facilitate subsequent removal of the core. The parts for this purpose are previously cleaned by pickling.

362,539. J. E. POLLAK, 20, Holborn, London.

Increasing the Creep Strength of Metals and Alloys.

As a result of intensive research, a method has been developed for increasing the creep limit or strength of iron, nickel, chromium or alloys comprising nickel, iron and chromium, the nickel content being above 50%, and the chromium content being between 12% and 30%, or iron and chromium, excluding nickel, in which the chromium content is between 20% and 40%, with or without additions such as molybdenum, aluminium, tungsten or manganese, for use as machine elements or furnace parts at temperatures above the recrystallisation temperature. The method consists in preheating the metals or alloys at temperatures between 1100° C. and the melting-point of the metal or alloy, and cooling at such a rate as to avoid internal stresses.

The application of the method consists in heating, for example, wires or strips in an annealing furnace in an inert atmosphere, like hydrogen or nitrogen, to a temperature above the temperature of use, exceeding the temperature of recrystallisation. This treatment increases the creep limit at the temperature of use. After annealing, cooling is effected slowly enough to avoid internal stresses, for which purpose thin articles may either be quenched or air cooled, whilst thicker articles are air cooled or cooled within an annealing box, or are cooled wholly or partly in the furnace itself after cutting off the heating supply.

Another method of heat-treatment, especially suitable for heating elements of electric furnaces, consists in heating them in the open air by an electric current on a table covered with a layer of firebricks to temperatures above 1100° C. for about 10 to 40 minutes, and afterwards switching-off the heating current rapidly or gradually, so that no internal stresses occur during cooling.

363,306. HEREAUS-VACUUMSCHMELZE, AKTIENGESELLSCHAFT, of Hanau am Main, Germany, patentee; Messrs. GILL, JENNINGS AND EVERY CLAYTON, Chancery Lane, London, W.C. 2., agents. Accepted December 15, 1931.

Melting Grey Iron in the Electric Furnace

(*Continued from page* 10).

Since borings, turnings, and similar light scrap have low market values, and are readily obtainable in most communities, they offer a means of producing high-test iron at very moderate costs. Table IV. illustrates the cost of molten metal produced in the indirect arc furnace from such charges.

The cost of duplexing cupola iron depends primarily upon two factors: the temperature of the cupola metal, and the quantity of steel added to the cupola metal in the electric furnace. The addition of 10% of steel is common practice for producing a 3·00% total carbon duplexed iron from a 3·30% total carbon cupola metal, and data based upon this procedure shows excellent results. These data, also, are based upon a cupola iron temperature of 2,650° F. (1,454° C.), and a duplexed iron temperature of 2,950° F. (1,621° C.), or a rise of 300° F. (167° C.). The process of synthesising grey iron from steel scrap has a great many applications, and the quality of the iron so produced is unusually high.

Sand Spun Pipes

(*Continued from page* 25).

Dust-extraction System.—This system is connected to strippers, blow-boxes, cooling drums, vibrating screen, and sand bunker, etc. The dust is exhausted in the first instance through a cyclone separator, by which the heavier particles are removed and deposited direct into a wagon. The light dust is passed to the bottom of a large vertical scrubber. In this, water-flushed grids catch the dust and deposit it at the bottom of the chamber, while comparatively clean air escapes from the top. Pumps draw off the liquid material and discharge it into a separator, from which the sludge flows to settling tanks, and the water is recirculated through the scrubber.

As regards the pipe produced from this plant, it is of the same external diameter in the body, and has a socket of the same internal dimensions as the British standard pipe. It can, therefore, be used with all British standard straight pipes and specials of the same nominal bores. Due to centrifugal action, a casting without gas cavities, blowholes, and non-metallic inclusions, is virtually guaranteed, and experience up to the present has amply confirmed this. The tensile strength of the metal is also increased, and for these reasons it has been possible to reduce the thickness of the sand-spun pipe as compared with the pit-cast variety. Hence the weight of a 16-ft. sand-spun pipe, which is the only length made, is approximately that of the standard pit-cast 12-ft. length, which facilitates transport and reduces the number of joints.

COOKING FOOD IN ALUMINIUM VESSELS.

CONSIDERABLE investigatory work has been carried out in an endeavour to determine the suitability of various metals for the construction of cooking utensils and food containers. The lightness and hygienic qualities of aluminium have been particularly emphasised both from theoretical and practical aspects. In such a sensitive product as milk, for instance, valuable considerations from a practical point in regard to aluminium, are that it imparts neither smell nor flavour to the milk under ordinary conditions. The advantages of this metal apparently compensate for the somewhat heavier initial cost compared with other metals in use for the purpose, for many of the leading countries are using aluminium very extensively in dairy equipment.

A necessary qualification of all materials that come into contact with food during its production, distribution, cooking, or service is that they must not in any way depreciate the quality of the food. Primarily, it is not permissible that any essential constituent of the food be removed or any harmful substance added. Of secondary importance is the requirement that a specific undesirable taste or odour should not be imparted, and that a discoloration should not be produced in foods by containers during any of the operations mentioned. It is, of course also of importance that the utensil be inert to corrosion by foods in order that it survive use in cooking.

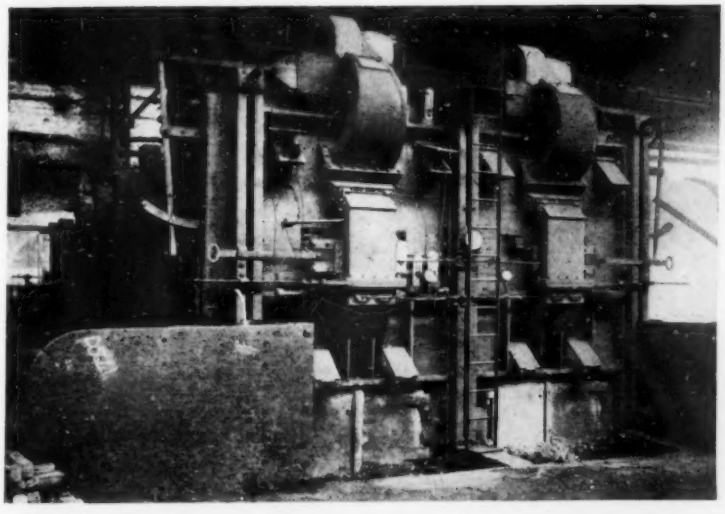
The wide popularity of aluminium after about thirty years of employment is convincing evidence that it is satisfactorily resistant to food attack, and that no harm results from eating foods customarily prepared in aluminium vessels.

Schwartze, Hann, and Unangst[1] have shown as a result of an investigation that only barely detectable amounts of aluminium appear in the tissues following diets containing large amounts of aluminium. The amounts of aluminium which enter foods by contact with aluminium in a variety of culinary practices have been studied.[2] The purpose of this investigation was to determine the amount of aluminium that enters food during cooking, and attention was directed to the food rather than the utensil. Foods cooked in glass and in aluminium were analysed for aluminium, and the results indicate that clean aluminium utensils are attacked to an insignificant degree by foods of neutral reaction. Acid foods or foods to which baking soda has been added dissolve small amounts of aluminium from utensils. Dark utensils yield more aluminium to foods than bright ones, but probably only in proportion to the quantity of stain. The few experiments with and without sugar indicate that sugar decreases corrosion of aluminium utensils. The largest amount of aluminium that these authors have found in any food was 118 p.p.m. in apple butter, which had been cooked in aluminium for 6·5 hours. Even this apparently large amount of aluminium (0·118%) is far less than the 1,400 p.p.m. that have been found necessary to produce symptoms of phosphorus starvation in animals on a low phosphorus diet. Obviously the aluminium content of the general run of aluminium-cooked foods is so far below the phosphorus content that it may be regarded as of no significance.

The data obtained from this investigation enable the calculation of the daily ingestion of aluminium in foods. In a balanced ration planned from the sixteen commonly used foods, it has been estimated that about 12 mg. of aluminium would be consumed if all the foods were cooked in aluminium. This amount is equivalent to approximately 4·9 p.p.m. in the ration chosen, of which 2·1 p.p.m. came from the utensil.

[1] Schwartze, Hann & Unangst, Ind. Eng. Chem., 24, 4, pp. 403-5.
[2] Beal, Unangst, Wigman & Cox, Ind. Eng. Chem., 24, 4, pp. 405-7.

HEAT-TREATMENT FURNACES



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ALL PURPOSES

and to use any fuel. Recuperative Furnaces for Producer Gas. Patented Smokeless Furnaces for solid fuel. Automatic temperature control with proportionate mixture of air and gas for all Town's Gas Furnaces.

THE "D.M." COAL-FIRED REHEATING FURNACE. This is a coal-fired Furnace with a characteristic "gas" flame. It is recuperative in that the primary and secondary air is preheated, the primary air being water vaporous. Perfect and easy control of the proportions is affected by handy levers. This "D.M." coal-fired furnace has effected a reduction in fuel costs of from 9/8 to 2/- per ton of steel treated; all costs are included, including "Stand by" and initial heating to working temperature. For heating bars, billets, plates, forgings, etc., this furnace is ideal. Perfectly smokeless in operation, it revises previous ideas on coal-fired reheating furnaces and is a wonder for economy.

The DOWSON & MASON GAS PLANT CO., LTD.

Alma Works, Levenshulme, Manchester.

MARKET PRICES

ALUMINIUM.

98/99% Purity	£95	0	0

ANTIMONY.

English	£35 0 0 to £42	0	0
Chinese	24	5	0
Crude	16	0	0

BRASS.

Solid Drawn Tubes	lb.	9d.
Brazed Tubes	lb.	11d.
Rods Drawn	,,	7⅞d.
Wire	,,	7⅜d.
*Extruded Brass Bars	,,	4⅜d.

COPPER.

Standard Cash	£30	0	0
Electrolytic	34	10	0
Best Selected	33	0	0
Tough	32	10	0
Sheets	63	0	0
Wire Bars	36	10	0
Ingot Bars	36	10	0
Solid Drawn Tubes	lb.	9¾d.	
Brazed Tubes	,,	9¼d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	2	3½
‡Ferro Tungsten	,,	0	2	0
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2-4% Carbon, scale 12/- per unit	ton	36	12	0
NOMINAL 4-6% Carbon, scale 8/- per unit	,,	27	10	0
NOMINAL 6-8% Carbon, scale 8/- per unit	,,	24	15	0
NOMINAL 8-10% Carbon, scale 8/- per unit	,,	24	10	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/6 per unit	,,	38	10	0
Guar. max. 1% Carbon, scale 14/ per unit	,,	42	0	0
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	46	0	0
‡Manganese Metal 96-98% Mn.	lb.	0	1	3
‡Metallic Chromium	,,	0	2	6
§ Ferro-Vanadium 25-50%	,,	0	12	8
§ Spiegel, 18-20%	ton	6	17	6
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	,,	8	17	0
45/50% basis 45%, scale 5/- per unit	,,	13	10	0
70/80% basis 75%, scale 7/- per unit	,,	18	17	6
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	12	5	0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20-25%	ton	21	10	0

FUELS.

Foundry Coke—						
S. Wales	£1	2	6 to	1	7	6
Sheffield Export	0	18	0 to	0	18	6
Durham				1	4	0
Furnace Coke—						
Sheffield	0	12	0 to	0	12	6
S. Wales	0	17	0 to	0	18	0
Durham				1	4	0

GUN METAL.

*Admiralty Gunmetal Ingots (88:10:2)	£50	0	0
*Commercial Ingots	41	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0 9½
*Cored Bars	,,	0	0 11½

LEAD.

Soft Foreign	£11	10	0
English	13	10	0

MANUFACTURED IRON.

Scotland—			
Crown Bars, Best	£10	5	0
N.E. Coast—			
Rivets	11	0	0
Best Bars	10	10	0
Common Bars	10	0	0
Lancashire—			
Crown Bars	9	15	0
Hoops £10 10 0 to	12	0	0
Midlands—			
Crown Bars £9 15 0 to	10	0	0
Marked Bars	12	0	0
Unmarked Bars	—		
Nut and Bolt Bars £8 7 6 to	8	12	6
Gas Strip	10	12	6
S. Yorks.—			
Best Bars	10	10	0
Hoops..Hoops £10 10 0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9½d.
*Cored Bars	,,	11½d.
†Strip	,,	10d.
†Sheet to 10 W.G.	,,	10½d.
†Wire	,,	11¾d.
†Rods	,,	11d.
†Tubes	,,	1/4½
†Castings	,,	1/1½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	8	6
Foundry No. 1	3	12	0
,, No. 3	3	9	6
N.E. Coast—			
Hematite No. 1	3	4	0
Foundry No. 1	3	1	0
,, No. 3	2	18	6
,, No. 4	2	17	6
Cleveland—			
Foundry No. 3	2	18	6
,, No. 4	2	17	6
Silicon Iron	3	1	0
Forge No. 4	2	17	0
N.W. Coast—			
Hematite	3	14	6
Midlands—			
N. Staffs Forge No. 4	3	1	0
,, Foundry No. 3	3	6	0
Northants—			
Forge No. 4	2	17	6
Foundry No. 3	3	2	6
Derbyshire Forge	3	1	0
,, Foundry No. 3	3	6	0
West Coast Hematite	3	6	0
East ,, ,,	3	3	6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	96 KRONOR.
Billets	£12 13 6 to £16 0 0
Wire Rods	£14 12 0 ,, £17 12 6
Rolled Bars (dead soft)	£10 4 0 ,, £11 11 0
Rolled Charcoal Iron Bars	— £16 0 0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£25	0	0
,, Brazier	22	0	0
,, Wire		—	
Brass	18	0	0
Gun Metal	21	0	0
Zinc	6	10	0
Aluminium Cuttings	72	0	0
Lead	8	0	0
Heavy Steel—			
S. Wales	2	2	0
Scotland	1	17	6
Cleveland	1	15	0
Cast Iron—			
Midlands	1	17	6
S. Wales	2	5	0
Cleveland	2	0	0
Steel Turnings—			
Cleveland	1	12	6
Midlands	1	2	0
Cast Iron Borings—			
Cleveland	1	6	0
Scotland	1	10	6

SPELTER.

G.O.B. Official		—	
Hard	£11	0	0
English	13	17	6
India	12	0	0
Re-melted	11	17	6

STEEL.

Ship, Bridge, and Tank Plates—			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	9	0	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E. Coast	10	0	0
,, ,, (Marine) ,,	10	10	0
Angles, Scotland	8	7	6
,, North-East Coast	8	7	6
,, Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails £8 10 0 to	8	15	0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic £8 2 6 and	8	12	6
Medium Basic £6 12 6 and	7	2	6
Soft Basic	6	0	0
Hoops £9 10 0 to	9	15	0
Manchester—			
Hoops £9 0 0 to	10	0	0
Scotland, Sheets 24 B.G.	10	5	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	2/-
Finished Bars 18% Tungsten	lb.	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to ⅛ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅛ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£129	10	0
English	130	15	0
Australian	130	15	0
Eastern	129	0	0
Tin Plates I.C. 20 × 14 box	14/6—15/-		
Block Tin (Cash)	120	12	6

ZINC.

English Sheets	£23	0	0
Rods	28	0	0
Battery Plates	19	10	0

* McKechnie Brothers, Ltd., quoted May 9. † C. Clifford & Son, Ltd., quoted May 9. ‡ Murex Limited, quoted May 9

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices quoted May 9, ex warehouse.